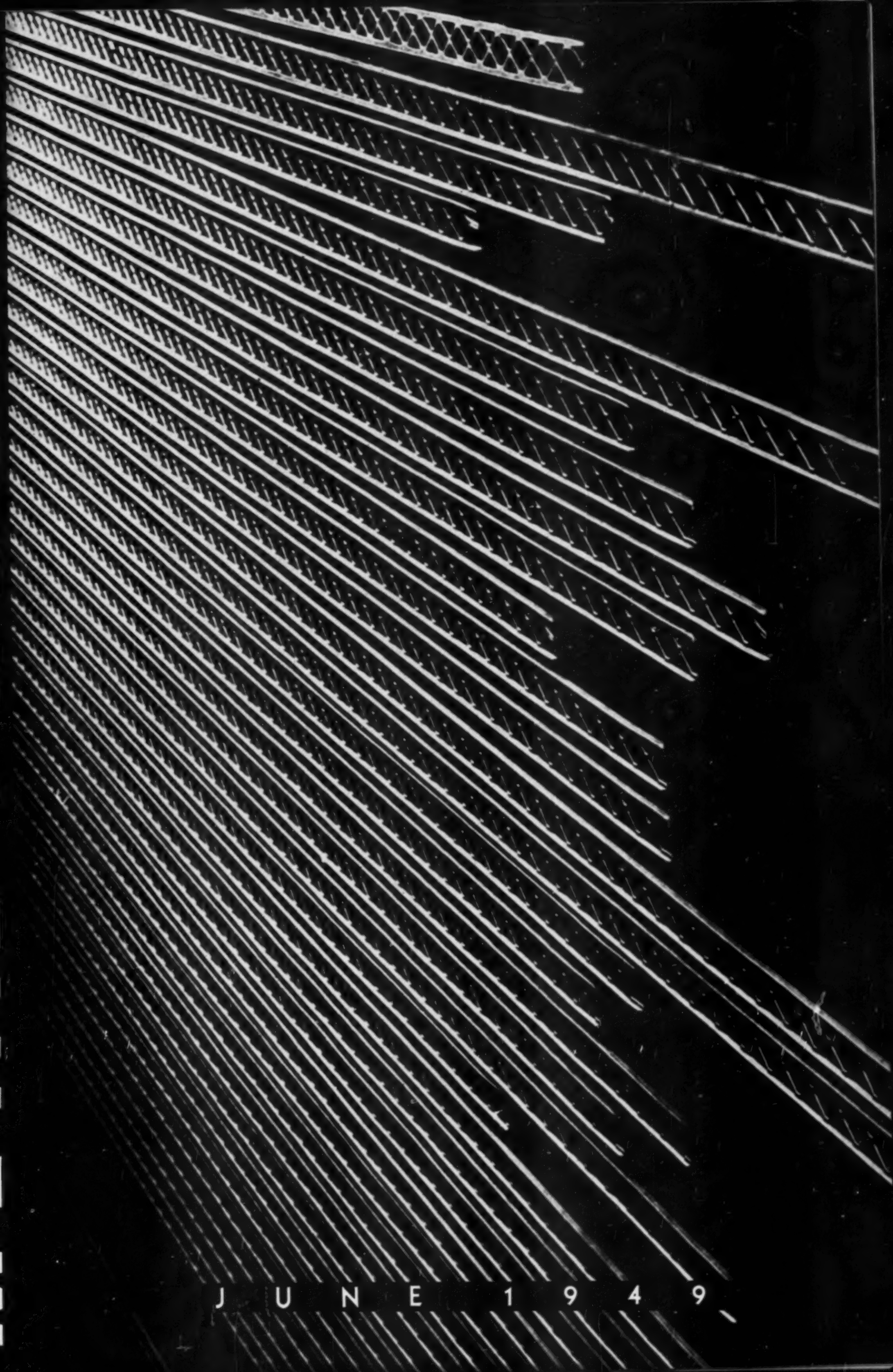
METAL PROGRESS



JUNE 1949

HOW CARBON CONCENTRATION CONTROL

BENEFITS THE ENTIRE METAL INDUSTRY

All industry benefits from the use of cold drawn bar stock that features cost-saving qualities and processing advantages such as—

- Uniform carbon content from center to surface.
- Improved machinability.
- No "decarb." Eliminates surface grinding and machining.
- Eliminates necessity of buying oversize stock.
- Costs so little more.

These advantages are possible as a result of the application of Gas Chemistry to heat treatment. The process is known as *"Carbon Concentration Control", introduced to the metal industry by 'Surface' researchers and engineers. Since then the practical application of this process of heat treatment has indicated outstanding advantages affecting metallurgical qualities, workability, and savings.

Write for bulletins on 'Surface' applications of Gas Chemistry to the heat treatment of metals.

SURFACE COMBUSTION CORPORATION
TOLEDO 1, OHIO

*"Carbon Concentration Control" reprinted in A. S. M. Transactions, Volume 38, 1947, PP 659–681.

'Surface' INDUSTRIAL FURNACES •

with TOCCO* Induction Heating

600 *parts per hour from this 50 KW, 10,000 cycle TOCCO Induction Heating Machine!*

This part—a shifting lever for famous Lima Power Shovels—may not resemble any part which you manufacture. However, if you're concerned with the profits of your company, it will pay you to investigate the application of TOCCO Induction Heating to any of your products which require hardening, brazing, soldering, annealing or forging operations.

● Progressive engineers at Lima-Hamilton Corporation, Lima, Ohio have adopted TOCCO Induction Heating for hardening the Shifting Lever shown here.

CUTS COST—TOCCO Induction Heating of this part saves over 4¢ per piece—$25 per hour—costs only 17% of former heating methods.

SPEEDS PRODUCTION—Automatic heating cycle is 4 seconds, quenching cycle 2 seconds, total production 600 TOCCO-hardened parts per hour.

VERSATILITY, TOO—This part is only one of *139 production parts TOCCO-hardened* by Lima-Hamilton Corporation. All 139 show substantial savings over conventional heating methods.

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Please send copy of "Typical Results of TOCCO Induction Hardening and Heat Treating".

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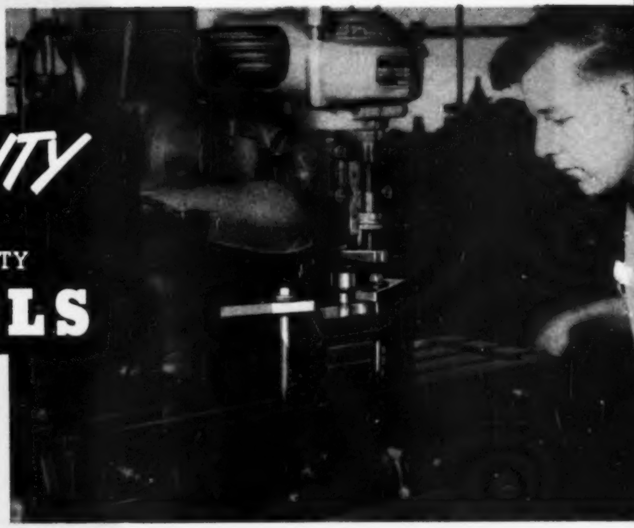
MEANS
IMPROVED MACHINABILITY
IN **DIE STEELS**



Machining Cobalt Chrome Die Steel at Brooke Russell Products.

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BRAND
HIGH SPEED STEELS
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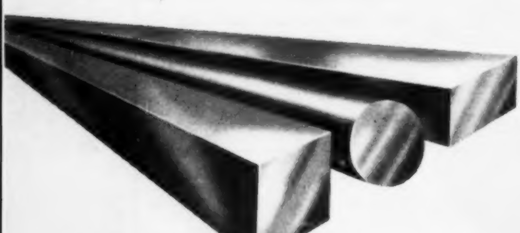
HIGH CARBON–HIGH CHROMIUM DIE STEELS

MACHINABILITY—AN IMPORTANT FACTOR! The full uniformity in Latrobe's Desegatized Brand Steels is a valuable aid to skilled machinists and tool and die makers, and provides experienced craftsmen with a material of superior machinability with which to work. Absence of hard carbide clusters in annealed Desegatized Brand tool steel means easier machining qualities, smoother and more accurate finished surfaces, and the elimination of chattering and tool breakage caused by hard spots in ordinary tool steels.

The uniform cross section of this bar of Latrobe's Desegatized Brand Cobalt Chrome Die Steel means greatly improved machinability with less damage to cutting tools while saving costly cutting time.

Large masses of hard carbide segregates seen in the center of this bar of ordinary die steel cause chattering, rapid tool dulling, and expensive machining time.

*TRADE MARK REGISTERED U. S. PAT. OFFICE



LATROBE ELECTRIC STEEL COMPANY
LATROBE, PENNSYLVANIA
BRANCH OFFICES AND WAREHOUSES LOCATED IN PRINCIPAL CITIES

Write or call your nearest Latrobe Sales Engineer for the complete facts on **LATROBE DESEGATIZED BRAND STEELS**

Improved Surface Qualities For Many Parts and Tools

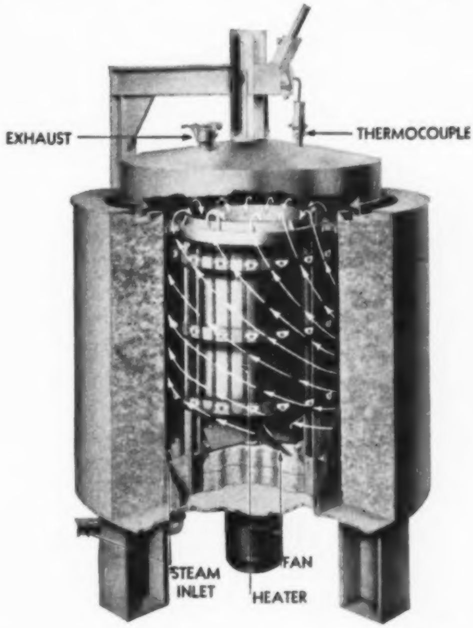
A new member of the familiar Homo family, the Steam Homo is specifically designed for steam atmosphere heat treatment between 750 F and 1150 F. Typical of the specialized applications of this method are the treatment of —

- powdered iron parts . . . for greater hardness, resistance to wear and corrosion
- twist drills and other tools . . . for longer life when cutting hard stock
- copper alloy parts . . . for easier cleaning before plating
- cast iron parts . . . for improved wear resistance
- steel parts . . . for faster, smoother machining and grinding characteristics

The Steam Homo Method combines four outstanding advantages:

(1) Steam atmosphere — for scale-free, blue-oxide finish.

(2) Homo forced-convection circulation — for rapid, uniform heat treatment.



Used with or without steam, interchangeably, Steam Homo is adaptable for straight tempering at all unusual temperatures, as well as for steam treatment. Driven by a powerful fan, hot steam swirls through the load, heats every piece rapidly and uniformly. Steam from a process line or small generating unit is fed through pipe in bottom of furnace.

A typical installation, showing milling cutters being loaded into furnace. Furnace Control panel is at right.

(3) Accurate Duration-Adjusting Type of Micromax Electric Control, fully proportioning — holds work at precise temperature.

(4) Micromax Record shows furnace cycles.

Compact and simple to operate, the Steam Homo Furnace handles big loads of small parts quickly and efficiently. It is so clean and quiet that it can even be installed right on the production line. It is a complete, integrated assembly of furnace and control instruments . . . engineered to operate effectively together.

Out Cat. T-625 Sec. 1 will be sent on request, or, if you have a specific application, an L&N engineer will call. Write to Leeds & Northrup Co., 4927 Stenton Ave., Philadelphia 44, Penna.

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Jrl. Ad T-620 (27)

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STAINLESS STEEL CASTINGS

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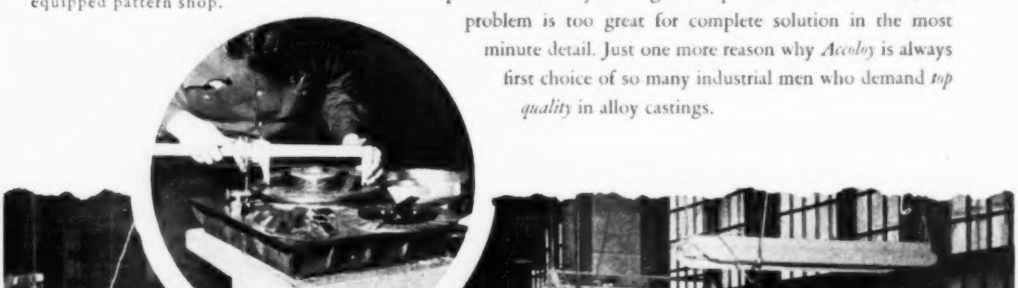
While maintaining the top quality for which *Accoloy* Castings are famous . . . while striving to give customers better, more complete service . . . we have developed in our own plant the most modern pattern shop of its size—anywhere! Here the finest tools obtainable, operated by long-experienced engineering craftsmen, are used to best possible advantage in making both wood and many metal patterns for alloy castings. No pattern is too intricate, no problem is too great for complete solution in the most minute detail. Just one more reason why *Accoloy* is always first choice of so many industrial men who demand *top quality* in alloy castings.

An engineering craftsman checks a complicated metal turbine wheel pattern in the Alloy Casting Company's modern, completely equipped pattern shop.



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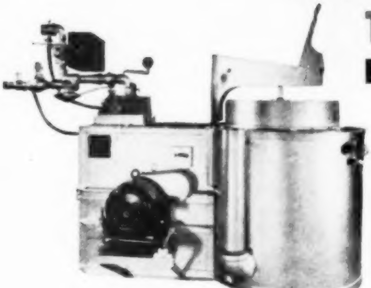
LINDBERG CYCLONE FURNACES TEMPER SCREWS AT $0.000 093 6 FUEL COST PER POUND



Lindberg Cyclone Furnaces can help reduce the costs and improve the quality of your tempering, annealing, nitriding, stress-relieving and non-ferrous heat-treating. Bulletin 53, "*Lindberg Gas Fired Cyclone Tempering Furnaces,*" tells how. Ask for it. (Bulletin 14 covers *Electric Cyclones.*)

Lindberg Steel Treating Co., Chicago, the world's largest custom heat treating organization and companion company to Lindberg Engineering Co., uses twenty-nine 100% forced-convection Lindberg Cyclone Furnaces for low-cost production tempering of many jobs—from tiny screws to 4 ton charges of forgings.

Here is one typical job, self-tapping screws tempered in one of the nine furnaces shown above (the third one from the front—it has a work chamber 22″ in diameter by 26″ in depth). Note the low unit cost.

FUEL COST	$0.000 093 6 PER LB.
Weight of charge	1019 lbs.
Temperature	600° F.
Time in furnace	65 minutes
Fuel consumed	159,000 BTU (1.59 Therms)
Fuel cost @ 6c Therm	9½c

Hardness is easily controlled to plus or minus 1 Rockwell "C." Heating is rapid and uniform. Heat is generated in a *separate* chamber away from the charge, *then* circulated by blower through all parts of the work chamber. All work is uniformly heated at the same instant—radiant heat does not reach outside of charge first . . . and center last.

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Built to Keep Instrument Up-Keep DOWN

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ElectroniK Potentiometers . . . strip chart, circular scale and circular chart . . . are fully explained and described in Catalog 15-13. A copy will be sent to you upon request . . . write today!

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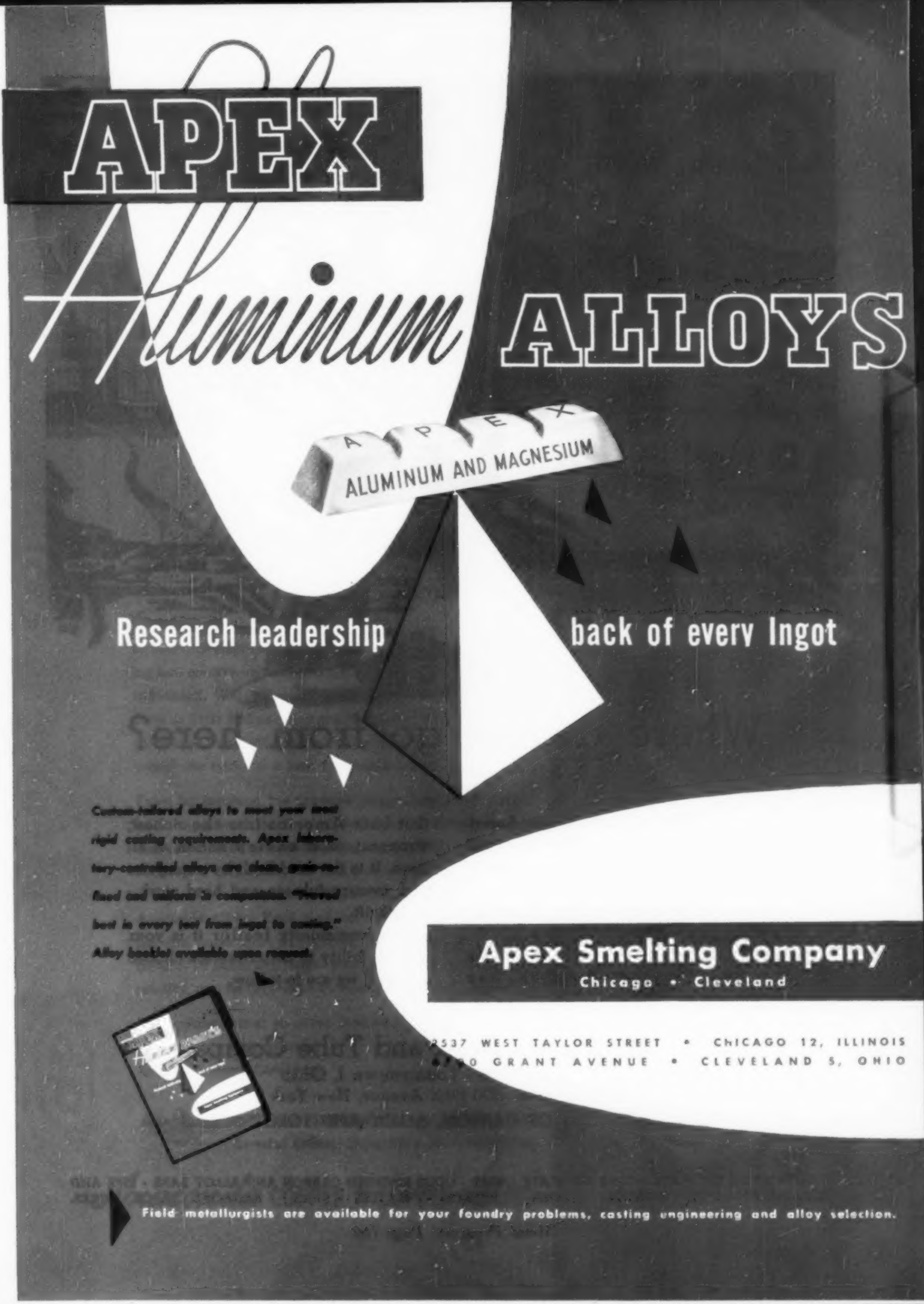
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The other way looks very much like the road we have traveled--the way that built America into the richest, strongest, most envied nation of all time. It is the road built by enterprise and resourcefulness and hard work--and thrift.

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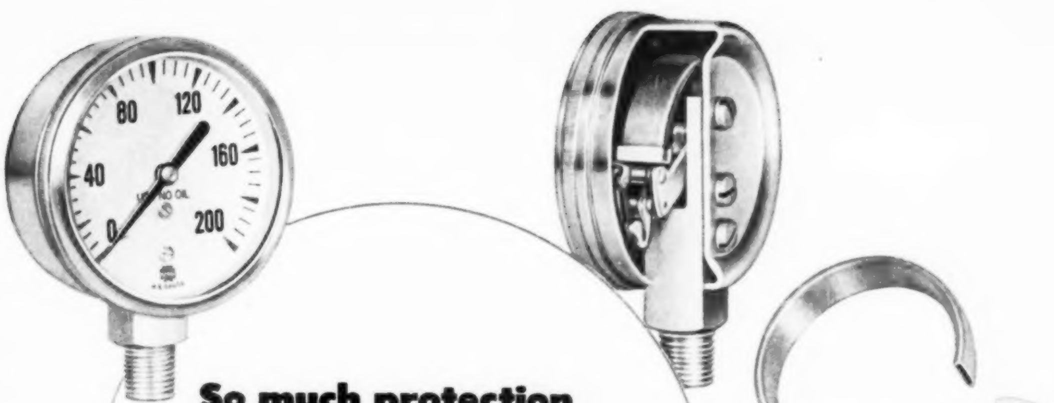

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Little wonder that so many instrument makers depend on Brass ... with so much of it from the mills of The American Brass Company. 46121

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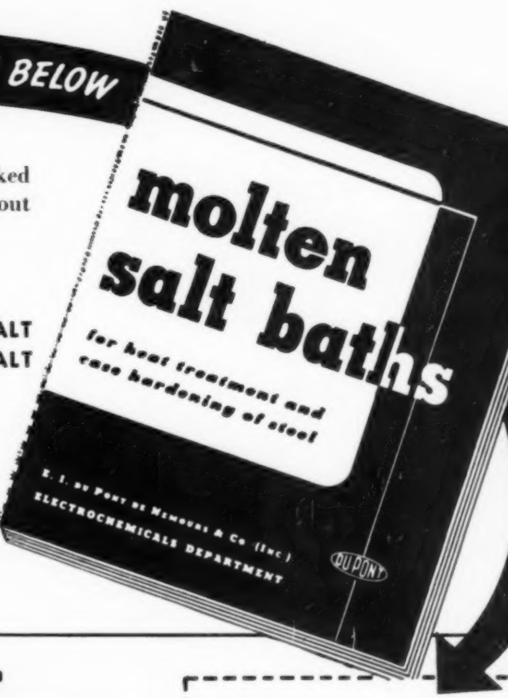

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for Steel Treating

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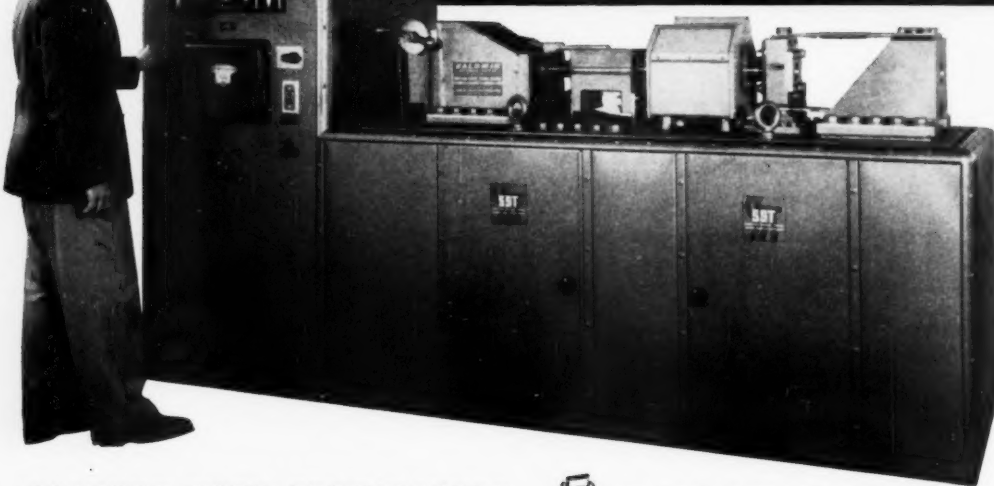
For Designers WHO WANT *COLD FACTS* ON "*HOT*" APPLICATIONS

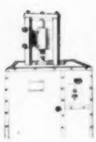


BALDWIN HIGH TEMPERATURE TESTING EQUIPMENT . . . There's a "fourth dimension" in testing today, bounding a new field where the properties associated only with length, breadth and thickness are inadequate to forecast performance.

This new dimension is *temperature*. The progress made to date in high-pressure steam turbines, in gas turbines, in jet engines, and in oil refinery equipment, has rested on the designers' knowledge of the effect of elevated temperatures on the properties of metals. Further progress will depend on the speed with which the horizons of this knowledge are expanded.

To aid explorers in this field, Baldwin has developed these interesting new items of high temperature testing equipment. Furnaces which are supplied as standard equipment are suitable for obtaining temperatures up to 1800° F. Special furnaces are available which will produce temperatures up to 2200° F.

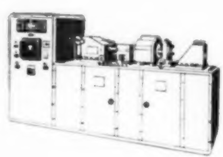
BALDWIN LEVER TYPE CREEP MACHINE. Maximum capacity 12,000 lbs. Loading accuracy within 1% of load, and accuracy of strain measurement is within .00005-inch. Over 150 of these machines are now in use in leading laboratories.



BALDWIN SONNTAG SF-4 FATIGUE MACHINE. The first "constant force" fatigue machine permitting application of furnace and control equipment for direct stress fatigue testing at elevated temperatures. Static pre-load 0 to 8,000 lbs.; dynamic load capacity ±5,000 lbs. Maximum capacity, one direction, 13,000 lbs.

BALDWIN SCREW TYPE CREEP RUPTURE MACHINE. Motor driven, capacity 20,000 lbs. Automatically maintains loads while temperature is held constant. Flat chart recorder plots elongation vs. time.

BALDWIN CONSTANT STRAIN RATE CREEP TESTING MACHINE. For determination of effect of various strain rates on the breaking points of metals, at controlled high temperatures. Head velocity can be varied from 0.6 inches to .000001-inches per second.



BALDWIN SONNTAG SF-5 FATIGUE TESTING MACHINE FOR TURBINE BLADES. Maintains a predetermined fixed load up to 8,000 lbs. while applying alternating flexure loads up to ±1400 lbs. at controlled high temperatures. Simulates service conditions.

HELPFUL TECHNICAL LITERATURE AVAILABLE. Technical bulletins, giving full details on the various equipment described above are available on request. Please indicate the machine in which you are interested, or the type of testing that you plan on doing.

The Baldwin Locomotive Works, Philadelphia 42, Pa., U. S. A. Offices: Boston, New York, Philadelphia, Houston, St. Louis, Chicago, Cleveland, Pittsburgh, San Francisco, Seattle, Washington. In Canada: Peacock Brothers, Ltd., Montreal, Quebec.

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An example of Penicillium, sp. Magnification 36x.

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Have you ever run into "sour" lubricants or coolants? Your nose will tell you when bacteria and mold are at work and your profits disappearing. Before that happens, control bacteria and mold with Dowicides—Dow's reliable industrial germicides and fungicides.

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Investigate Dowicides now. Find out how Dowicides can protect your profits from microorganisms. Complete laboratory facilities are maintained by Dow to help you solve your bacterial and mold problems. Contact your nearest Dow office or write direct to Midland.

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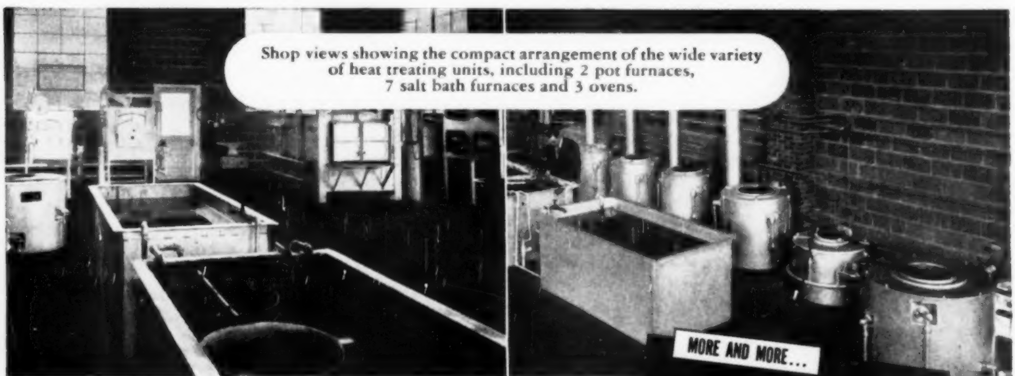
Emphasizes the Versatility of GAS

VARIETY is one of the most characteristic features of a commercial heat treating shop—variety of customer demands and variety of equipment required to fulfill them.

With a background of 22 years experience, Evan D. Ehmann, President of Superior Metal Treaters, Inc., knew just what to look for when he established his Newark, New Jersey, shop. This modern plant has the productive capacity to cope with the miscellaneous requirements of many customers.

Key feature of the installation is the versatility of the equipment. Each unit was chosen for its ability to perform under a number of different conditions. In selecting this equipment Mr. Ehmann determined to use GAS because, as he expresses it, **"During my years in this business I discovered that Gas Equipment provided the accurate control, economical operation, and versatility we needed. The precise temperatures and speed of heating we obtain with GAS mean a lot of extra production in our shop."**

Whether the heat treating process is a production-line application, or a commercial shop operation, the flexibility of GAS and the versatility of modern Gas Equipment are important economic factors. The characteristics of GAS make it stand out in any comparison with other available fuels for heat processing.



Shop views showing the compact arrangement of the wide variety of heat treating units, including 2 pot furnaces, 7 salt bath furnaces and 3 ovens.

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with no under bead cracking, minimum porosity, low spatter loss and ample penetration

No. 312 Electrode for Mild Steel (E-6016)
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Due to the extremely low hydrogen content of the weld deposits, Airco No. 312 (all position A-C or D-C) is especially recommended for welding hard-to-weld steels (without preheating) such as hardenable steels . . . high sulphur free machining steels . . . cold rolled steels . . . low alloy or mild steels where stress relieving cannot be employed . . . and steels to be vitreous enamelled after welding.

Airco No. 394 (all position A-C or D-C) provides low hydrogen content weld metal deposits of *high tensile strength* on hardenable steels without pre-heat or post-heat treatment. It is also used on carbon steel containing 0.30% or more carbon and should be used on steel containing alloying elements in addition to a high carbon content.

For more information about Airco Nos. 312 and 394 Electrodes, write your name and address on the margin below and send it to your nearest Airco office or authorized dealer for a copy of Catalog ADC-650A.

More news about AIRCO products

NO. 387 ELECTRODE (E-6012)

A high speed all position electrode (D-C or A-C) — ideal for welding mild steel when fit-up is poor. It exhibits excellent operating characteristics, particularly when welding vertically down, and produces a minimum of spatter. Airco No. 387 maintains a high degree of welding performance throughout the entire length of the electrode when high currents are used.

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Specifically designed for producing machinable welds in cast iron. Deposits are smooth and uniform, bonding well with the cast material; free from internal and surface porosity; and make water-tight joints. Also, color of deposits will approximate that of cast iron. No. 375 can be used in all positions with A-C or D-C.

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This new alloy (for oxyacetylene and electric application) is especially recommended for pulverizer hammers, coke crusher rolls, and similar parts, subject to *severe abrasion and medium impact.* With one application of this wear-retarding material, the service life of both new and worn parts is increased, in some cases, at least 25 times.

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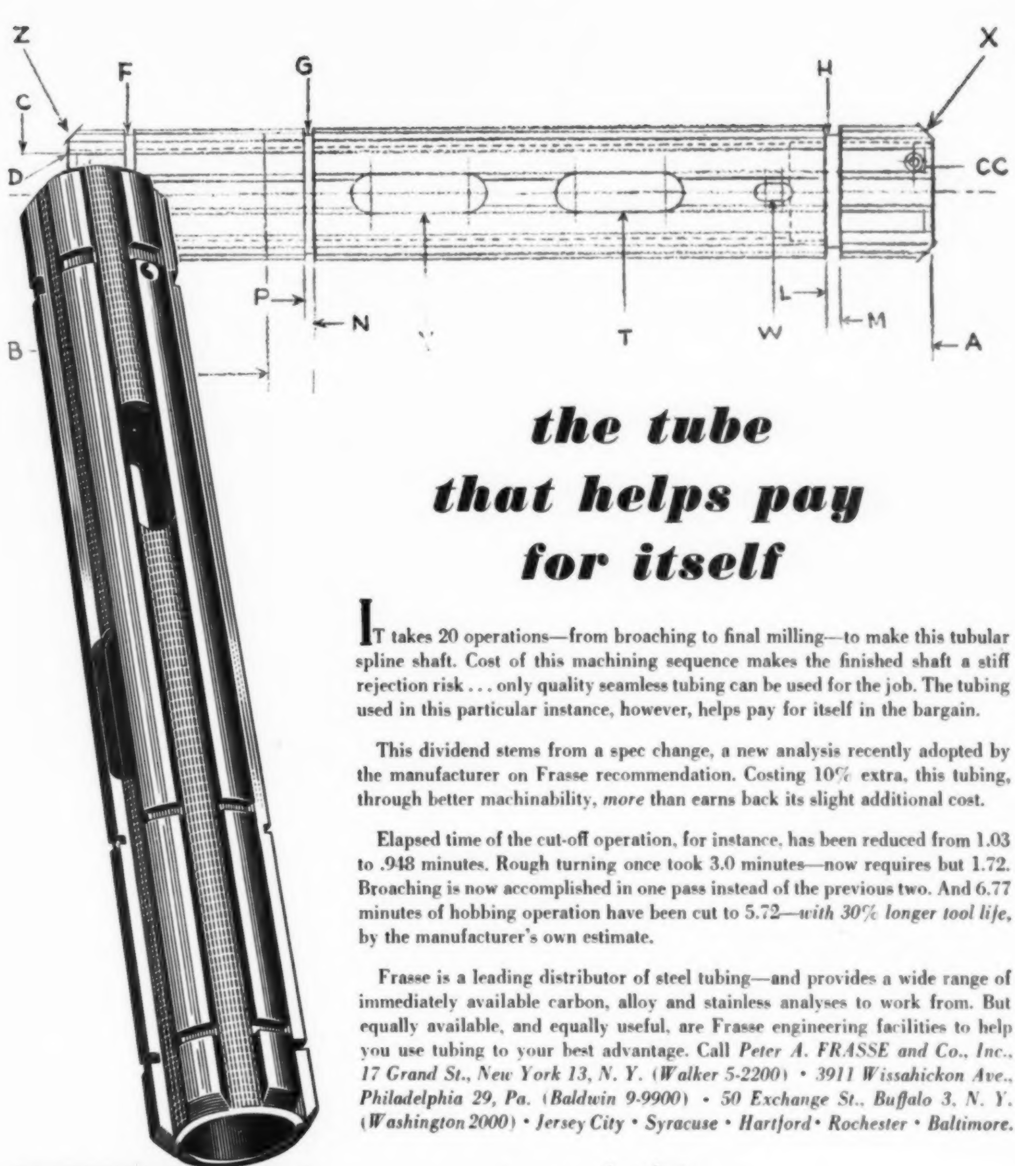
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COSTS CUT, TIME SAVED

in Open-Hearth Flues built with adaptable *LUMNITE Refractory Concrete

CONSTRUCTION: A 50% saving in cost was realized. In addition, construction time was considerably reduced by using LUMNITE Refractory Concrete on this job in 1943. This complex system of curved walls and tapered arches was cast in place without trimming, cutting or fitting. The Refractory Concrete was made with LUMNITE calcium-aluminate cement and aggregate prepared on the site from salvaged fire-clay brick. The cost advantage was reaffirmed later when two other sets of open-hearth flues connecting checkers and stacks were rebuilt with Refractory Concrete at the same steel mill.

SERVICE: Observe, in picture (lower right, above), the excellent condition of these same flues after five years' service. Note the sharp angles and smooth curves. There are no ragged walls, no flattened arches—no debris on the floor. With its monolithic, one-piece construction, there are no small units to work loose and weaken the structure. Excessive heat does not cause the Refractory Concrete to deteriorate. Maintenance expenses stay low. Installations are ready for service within 24 hours or less after placing.

• • •

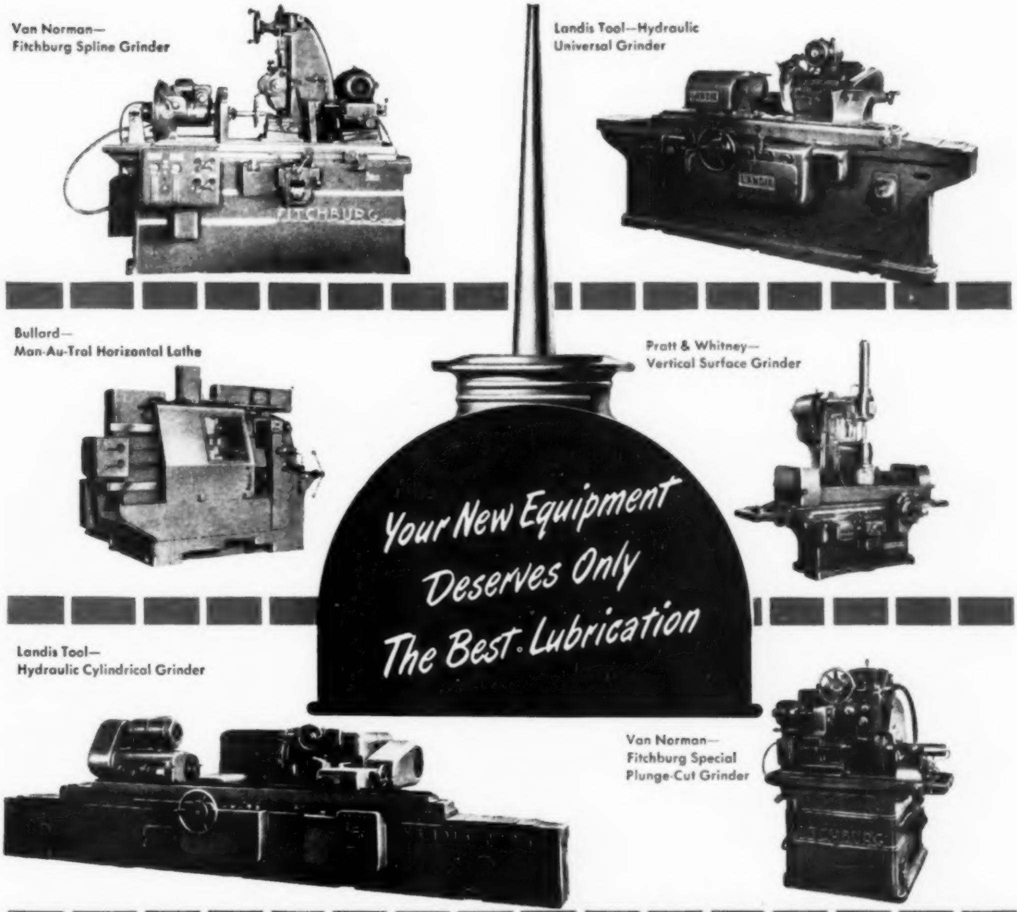
FOR BOOKLET describing these open-hearth flues and a manual on Refractory Concrete, write Lumnite Division, Universal Atlas Cement Company (United States Steel Corporation Subsidiary), Chrysler Building, New York 17, N.Y.

MP-L-12

"LUMNITE" is the registered trade mark of the calcium-aluminate cement manufactured by Universal Atlas Cement Company.

LUMNITE® — A UNIVERSAL ATLAS PRODUCT — FOR REFRACTORY CONCRETE

"THE THEATRE GUILD ON THE AIR"—*Sponsored by U. S. Steel Subsidiaries—Sunday Evenings—ABC Network*



Get Skilled Cities Service Lubrication From the Start

More than *14 billions* of *dollars* will be spent on new plants and new equipment in 1949. The smartest investment you can make for the maintenance and protection of your new equipment is to begin with a sound lubrication program.

In setting up lubrication schedules for new equipment why not first investigate the advantages to be gained by using Cities Service fine quality petroleum products. Whatever the make and model of machine you'll find the right lubricant to meet your particular requirements. Moreover, an experienced Cities Service Lubrication Engineer will be on hand to provide sound recommendations on any kind of lubrication problem. You will find him especially well-informed on the lubrication requirements of the latest types of metal working machinery.

FREE...
This New Fact-Filled Booklet For The Metal Machining Industry

- Cities Service Oil Company,
Sixty Wall Tower, Room 415
New York 5, N. Y.

Please send me without obligation your new booklet on "Metal Cutting Fluids."

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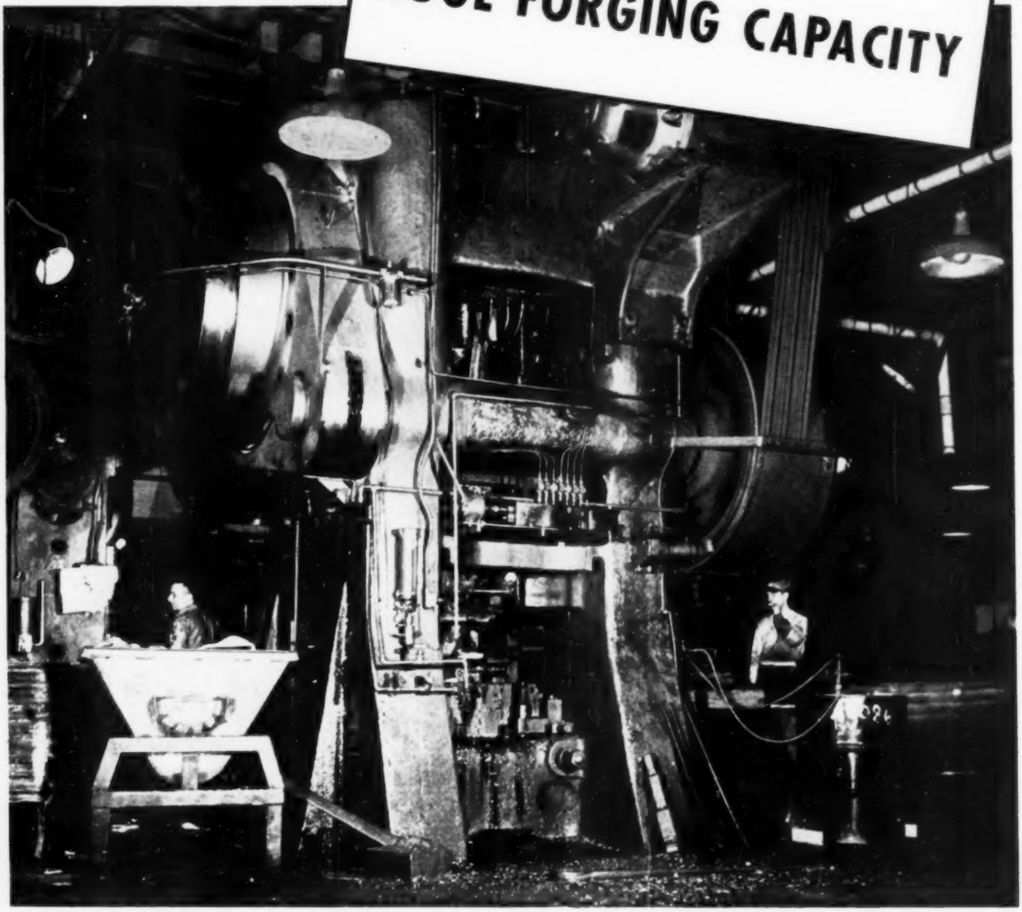
CITIES SERVICE

for your forging needs—

WILLYS-OVERLAND HAS HUGE FORGING CAPACITY



This 1500-ton hot forging press is among the huge battery of modern equipment in The Willys-Overland Forge.

The Willys-Overland Forge has capacity to produce 80 *million pounds* of quality forgings a year . . . ample for your forging needs and the demands of many new customers.

Before placing your next order for forgings, check with The Willys-Overland Forge. You may realize substantial savings in better forgings more adaptable to your specific requirements.

DROP FORGINGS

HOT PRESS FORGINGS

UPSET FORGINGS

Send for full information on one of America's great forges

THE WILLYS-OVERLAND FORGE

WILLYS-OVERLAND MOTORS • TOLEDO 1, OHIO

Bulletin on SUPER REFRACTORIES by CARBORUNDUM

TRADE MARK

NO. 3 JUNE, 1949

Using Super Refractories to Advantage

Super Refractories designed and produced by CARBORUNDUM are virtually *custom built* to meet a variety of operating conditions . . . conditions created by such variables as furnace-type, fuel, working temperatures, cycle, and material or ware being handled. Because of the complexity of selection factors, it is a good policy to consider each installation as a special case.

This line of super refractories consists of many varieties that offer a broad scope of refractory characteristics. Each of these variations is the result of solving special operating problems where other refractories failed to give satisfactory service. Because of the broad range of characteristics they provide, the wise use of these super refractories makes possible greatly improved performance in many furnace and kiln operations.

Their real economy has been demonstrated time and time again under circumstances varying from relatively low to extremely high temperatures. As frequently happens, a few brick or shapes eliminate costly localized trouble spots. On other occasions, complete installations have saved plants thousands of maintenance dollars.

To get the most from these super refractories, it is necessary to make careful problem analysis and then, judicious product selection. It's at this point that CARBORUNDUM engineers can be most helpful. They are technically trained in the fields of ceramic, chemical and mechanical engineering. Possessing extensive product knowledge and application experience, they fit the super refractory to the job. Their services are available promptly on request.

Physical Properties of Super Refractories by CARBORUNDUM

TRADE MARK

	CARBOFRAX	MULLFRAX	MULLFRAX S	ALFRAX K	ALFRAX B	ALFRAX BI
Heat Conductivity at 2200°F. in BTU/hr. sq. ft. and °F. /in. of thickness	109 BTU	16 BTU	9 BTU	24 BTU	12 BTU	7 BTU
REFRACTORINESS PCE CONE	37-40	38-39	37-38	37-39	39-40	38-39
SPALLING RESISTANCE	High	High	High	Good	Good	Good
ABRASION RESISTANCE	High	Medium	Medium	High	Medium	Low
THERMAL EXPANSION (25°—1400° C.)	.0000044	.0000059	.0000069	.0000074	.0000086	.0000086
MODULUS OF RUPTURE @ 2460° F. PSI	800-3125	100-250	175-475	100-1050	100-225	50-100
WEIGHT 9 IN. STRAIGHT	9.25 lbs.	9 lbs.	8 lbs.	10.1 lbs.	7.25 lbs.	4.8 lbs.

FIRST ONE—THEN ALL SIX

This battery of six crucible-type, oil fired melting furnaces is operated 5 days a week turning out 8 to 10 heats daily. Alloys of brass, bronze and nickel bronze are melted. At first, only one furnace was equipped with a CARBOFRAX silicon carbide lining. After more than a year's service, records were examined carefully. Among the important benefits realized were longer lining life, less patching, and lower maintenance costs. Greater furnace efficiency was obtained as the thinner lining, 1¾" thick, permitted use of more insulation to lower heat capacity . . . conserve fuel.

As a result all six furnaces are now lined with CARBOFRAX tile . . . all operate at a higher rate of efficiency and economy.

New Informative Booklet for Boiler Furnace Operators

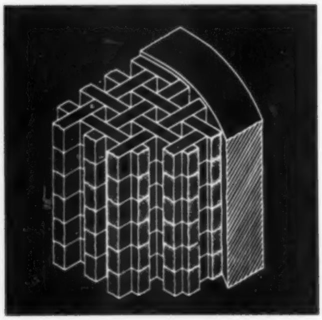
In 32 amply illustrated pages, this new bulletin details uses and advantages of specialized super refractories in a variety of boiler furnace installations. Unique characteristics of these products are presented. Their advantages, in both cooled and non-cooled furnace linings, are explained. Line drawings indicate suggested locations for profitable usage. Copies may be obtained upon request. There is no charge.

Address all correspondence to: Dept. J-69. THE CARBORUNDUM COMPANY, Refractories Division, Perth Amboy, New Jersey

Continued on other side →

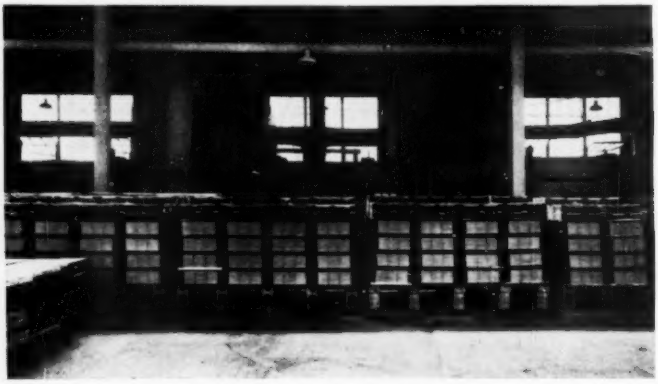
← Continued from other side

Added Help for More Gas-Make at Lower Cost

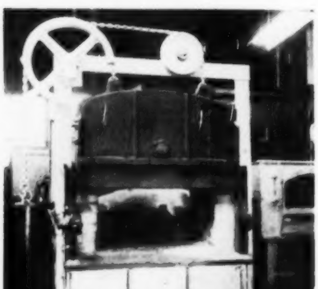


Improved oil efficiency, increased oil cracking capacity, solid fuel savings, and a reduction in checker maintenance are promoted by CARBOFRAX silicon carbide checker brick. Used in carburetors, super-heaters and oil gas generators, these checkers absorb more heat in shorter intervals. During the regenerative cycle this heat is released rapidly to the gas stream. Faster heat absorption and release are made possible by the high thermal conductivity and emissivity of CARBOFRAX brick. Their unique refractoriness, greater density and low iron content assure extended life and cleaner checker settings over longer periods.

Ceramic Producer Boosts Output 40%

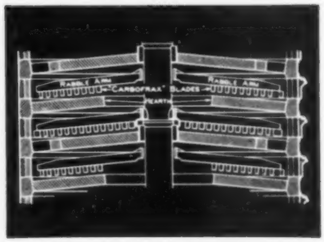


This manufacturer of wall and floor tile is using super refractories to good advantage. Switching from clay saggers to open setting has increased car capacity by 40%. Car schedule is continued at previous maximum level. The bisque wall tile are fired on CARBOFRAX silicon carbide tile and I-beam posts using 3-point support. The floor tile are burned in CARBOFRAX saggers on top of the car. After each trip, cars are torn down and reset. Due to greater mechanical strength and superior refractory characteristics, CARBOFRAX kiln furniture supports these heavier loads, resists handling, stands up under fast cycle... stays clean... does not warp or blister. It minimizes spotting . . . reduces rejections.



This Hearth Resists Mechanical and Thermal Abuse

Heavy castings are thrown in on this hearth with no attempt to avoid severe impact. The cold work is charged into the hot furnace and brought up to 1650°F. After a year of this severe service, the CARBOFRAX silicon carbide hearth remains straight and true... is perfectly level to accommodate long pieces that must be kept straight during normalizing and annealing. The high thermal conductivity of CARBOFRAX tile gives added advantages. More work is now being handled in this furnace, cycles are faster, and costs are far lower than when a fireclay hearth was used.



Tough Structural Problem Solved with Super Refractories

In this multiple hearth furnace — inside diameter 20 feet, height about 85 feet, with a total of 11 hearths — the lower 4 hearths present a very tough structural and service problem. Here, conditions are the most severe... temperature highest. Refractory materials originally used here gave a maximum service of less than *two months*. Such frequent replacement was expensive and recurring furnace shutdowns seriously hampered production. That was the situation when MULLFRAX electric furnace mullite brick were installed in this trouble zone. After four and a half years service, only one hearth required replacement. The remaining three MULLFRAX hearths appear capable of rendering several years additional life.

A complete file of informative literature covering super refractories is available through The Carborundum Company. There are facts and figures on installations in specific fields. To obtain copies of reports, booklets and catalogs of particular interest is a simple matter. Merely select from the list printed here. Copies will be sent you at once. No obligation, of course.

Super Refractories by CARBORUNDUM (general catalog)

Super Refractories for the Ceramic Industry

Super Refractories for the Process Industry

Super Refractories for Boiler Furnaces

Super Refractories for Heat Treatment Furnaces

Super Refractories for Gas Generators

The FRAX Line of Cements

CARBOFRAX Refractory Skid Rails

Bulletins Nos. 1, 2, 3 on Underdrain Systems and Diffuser Media

Dept. No. J-69

THE CARBORUNDUM COMPANY

Refractories Division

PERTH AMBOY, NEW JERSEY

Photos courtesy of:
1 and 2: American Gas Furnace Co.
3: York Corporation
4: The Fafnir Bearing Co.
5: The Union Fork & Hoe Co.

This is what we mean: Furnace parts and fixtures made of D-H cast alloys, such as Nichrome* and Chromax*, give top-level performance and *stay on the job* despite punishing cycles and high rate quenching . . . because exclusive Driver-Harris techniques endow these alloys with heat and corrosion-resistant properties that assure exceptional efficiency, long life and dependable service under the toughest conditions.

That is why, in hundreds of plants from coast to coast, you find D-H castings still on the job after thousands of hours of operation.

Take examples such as these:

1. In rotary gas carburizers such as this, large Nichrome retorts (averaging 1,800 pounds of work) have served up to 24,000 hours apiece at temperatures approximating 1600°F.

2. In this vertical carburizing furnace, operated at 1650°F., a Nichrome retort of 30" inside diameter has given 36,000 hours of trouble-free service.

3. The Nichrome baskets and fixtures shown here, used for hardening stainless steel impeller blades, "stand the gaff" for years—despite punishing cycles that include heating to 1825°F. and exceptionally high rate quenching.

4. In this annealing furnace for forged ball bearing rings, one of a battery of 14 operated at nearly 1500°F., cast Chromax baskets carry the work, furnace elements of Nichrome strip supply the electric heat. Continuously subjected to heating and cooling, the baskets stay on the job 6-8 years without need of repair; the heating elements give top-level performance for 15-20 years.

5. This 1450-pound Nichrome pot, holding 2 tons of molten lead, acted as heating medium for shovels and forks during hardening operations (at 1550°F.) for over 26,000 hours before being removed from the furnace.

Outstanding benefit of service such as this is the *paramount* advantage of *low heat-hour costs.*

Whatever *your* heat-treating problems you'll find D-H alloys unsurpassed for conventional applications, indispensable if particularly exacting requirements must be met. So consult with us. The fruits of our nearly 50 years of experience are at your service.

Nichrome (HW) and Chromax (HT) Castings
are manufactured only by

Driver-Harris Company

HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco, Seattle

*T.M. Reg.U.S.Pat.Off.

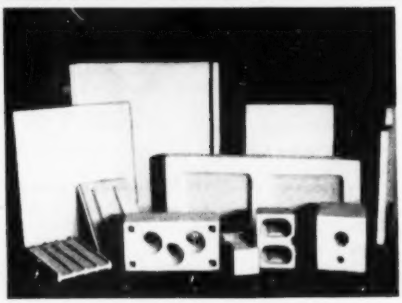
Taylor Sillimanite Refractories

Stand up in heavy-duty heat treating furnaces

You'll get longer refractory life for your heavy-duty or high-speed heating and heat treating furnaces with Taylor Sillimanite installed. TASIL Brick, Hearth Tile, Burner Blocks, Piers and Special Shapes are selected by many of the leading manufacturers of furnace equipment for their volume stability, high hot load strength and excellent resistance to repeated heating and cooling. TASIL pays off in the *long* run!

Also available are TASIL Ramming Mixes in several grades to meet varying service conditions. Specify TASIL Ramming Mix No. 213 for cold patching and Burner Blocks 2" in thickness and over; TASIL No. 214 for Burner Blocks under 2" in thickness.

Furnaces lined and maintained with Taylor Sillimanite last longer, attain greater efficiency, reduce refractory costs. Complete data on TASIL Refractories and Ramming Mix will be sent on request. Get full details today.



ALL TASIL Refractory Shapes are rigidly inspected for workmanship and accuracy, and can be installed with minimum furnace down-time.

Exclusive Agents in Canada:
REFRACTORIES ENGINEERING AND SUPPLIES, LTD.
Hamilton and Montreal

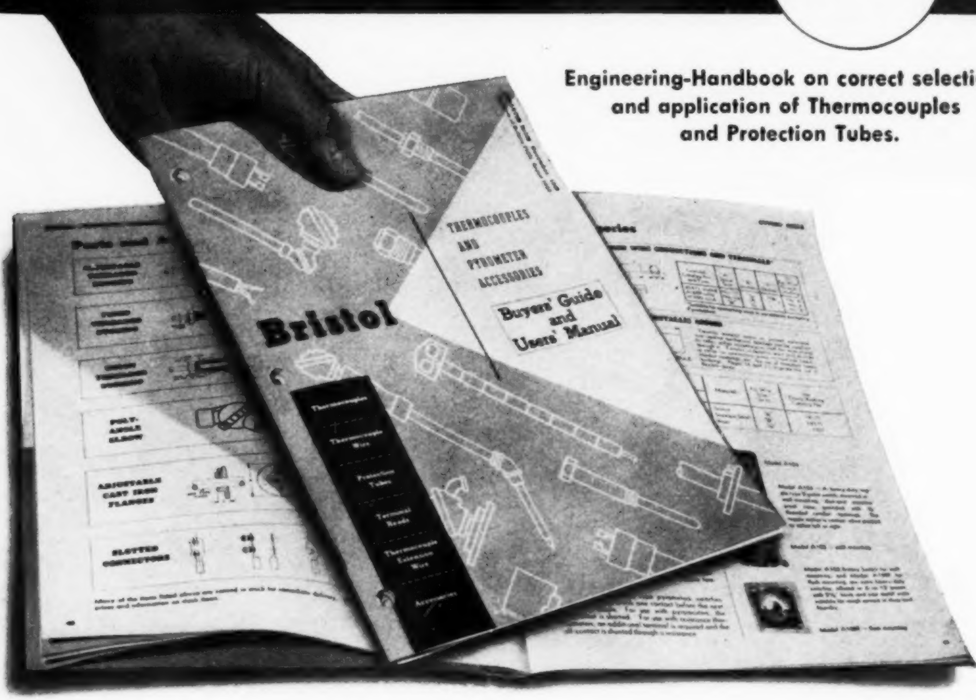
The CHAS. TAYLOR SONS Co.

MANUFACTURERS OF REFRACTORIES • CINCINNATI • OHIO • U.S.A.


A fastening practice
that makes Perfect Joints
FASTEN ALUMINUM WITH
ALUMINUM FASTENERS

IF YOU USE PYROMETERS . . . YOU NEED THIS NEW BOOK

FREE!



Engineering-Handbook on correct selection and application of Thermocouples and Protection Tubes.

Not only a complete, easy-to-use compilation of Bristol's line of modern thermocouples and pyrometer accessories . . . it's also a *textbook* on thermocouples.

When you consider that Bristol was the originator of commercial pyrometers in this country, you can easily see how much "know-how" must have been put inside the covers of this bulletin.

You'll find tables and charts useful in quickly selecting the right thermocouple and protection tube . . . illustrations of typical applications . . . tables of calibration data . . . PLUS a conveniently indexed and carefully illustrated catalog of the complete Bristol line of thermocouples, wire, protection tubes, insulators and accessories.

Have this 56-page combination Handbook and Buyers' Guide always on your desk. Send coupon for *your* free copy today. THE BRISTOL COMPANY, Waterbury 91, Conn. (The Bristol Company of Canada, Ltd., Toronto, Ont.; Bristol's Instrument Co., Ltd., Lynch Lane, Weymouth, Dorset, England.)

Send coupon for your copy

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Engineers Process Control for Better Products and Profits

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Yes, I want that new pyrometer guide of yours. Please send a free copy to

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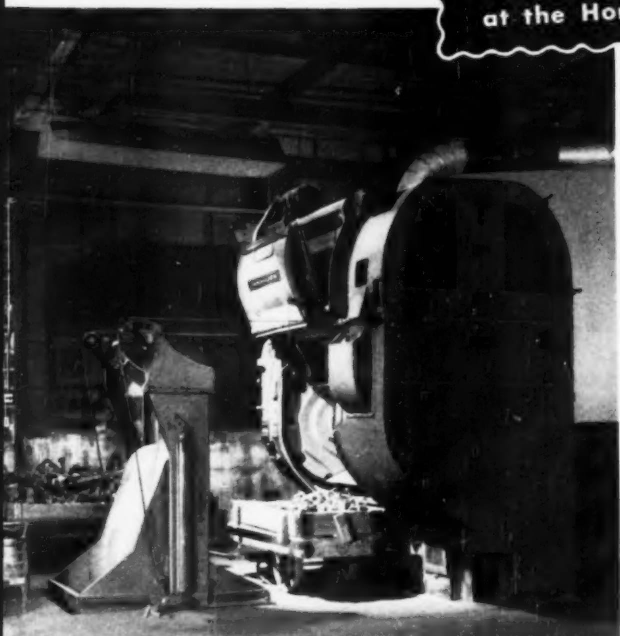
Eight years of continuous use proves ROTOBLAST* cleans faster ... better ... cheaper!

at the Homer Furnace and Stove Co.

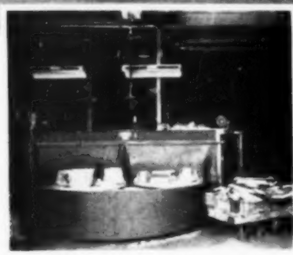


PRODUCTION SOARED as soon as this 14 cubic foot ROTOBLAST Barrel was installed at Homer Furnace and Stove Co. in 1941! Blast cleaning costs were reduced to rock bottom . . . and castings were completely cleaned . . . even those with hard-to-reach pockets!

Two years later Homer added a 14 foot diameter Pangborn ROTOBLAST Table to their cleaning equipment. The ROTOBLAST barrel-and-table team drove production figures *even higher!* Gave the company high-quality blast cleaning at low cost on all their castings!

Pangborn ROTOBLAST saves money for hundreds of users like Homer Furnace and Stove Co. Find out how it can do the same for you! General details are given below . . . but for *specific information* fill in the handy coupon and mail today!

Pangborn *ROTOBLAST cleans most effectively at lowest cost per hour of operation! It directs all the abrasive on a given target with the highest velocity for a given peripheral speed.* ***Cleans faster*** *because it throws greater volume of abrasive, covers a larger area with greater density!* ***Cleans better*** *because it produces a finer surface than old-style methods!* ***Cleans cheaper*** *because it requires less horsepower to propel abrasive, uses less manpower, minimizes maintenance, eliminates air compressor investments! Send coupon for full information today.*



This ROTOBLAST Table cleans all sizes of castings quickly and cheaply . . . Teams up with Barrels to boost Homer's casting output!

MORE THAN 25,000 PANGBORN MACHINES SERVING INDUSTRY

FREE BOOKLET COUPON

PANGBORN CORPORATION
1404 Pangborn Blvd., Hagerstown, Md.

Send me free information on Pangborn ROTOBLAST. I am interested in: ( ) Barrels ( ) Tables ( ) Rooms

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Pangborn

* Trademark of the Pangborn Corporation

BLAST CLEANS CHEAPER with the right equipment for every job

The Case of the Complete Coverage

The McKay Stainless Electrode line completely covers your requirements for electrodes to weld all types of stainless-steels including the extra low carbon, chrome-nickel steels; the high nickel-chrome, heat-resisting alloys; and the new steels developed for the high-temperature alloys used in super-chargers, heat turbines, jet engines and rockets.

McKay Stainless Electrodes—in Lime, DC Titania and AC-DC coatings—are especially designed to deposit weld-metal similar in chemical analysis and physical properties to the stainless-steels welded with them.

McKay Lime Coated Electrodes are characterized by large, hot arc puddles. The slag, though fluid when molten, freezes quickly and so makes it easy to weld in vertical positions without having the weld-metal fall away from or into the weld.

McKay DC-Titania Coated Electrodes have small, restricted arc puddles and slag that moves quickly away from the arc . . . with the result that there is no slag interference with the arc action and weld beads are smooth and finished. Low spatter loss and easy slag removal make these electrodes ideal where ease of welding and good weld appearance are important.

McKay AC-DC Coated Electrodes are recommended for their arc stability, low spatter loss and ease of operation in vertical, overhead and other positions. They strike and restrike easily with little or no tendency to stick or freeze. The slag produced is easy to control and does not interfere with the arc action. Weld beads are smooth and uniform.

Your inquiries are invited on standard and "special" McKay Stainless Electrodes. Immediate delivery on standard grades.

* * * * * * * * * * * * * * *

McKAY STAINLESS-STEEL ELECTRODES

McKay Welding Engineers will gladly advise you, without obligation on the selection of electrodes and the most efficient welding procedure to obtain best results when welding stainless-steels.

WRITE FOR CONDENSED DATA SHEET ON STAINLESS ELECTRODES

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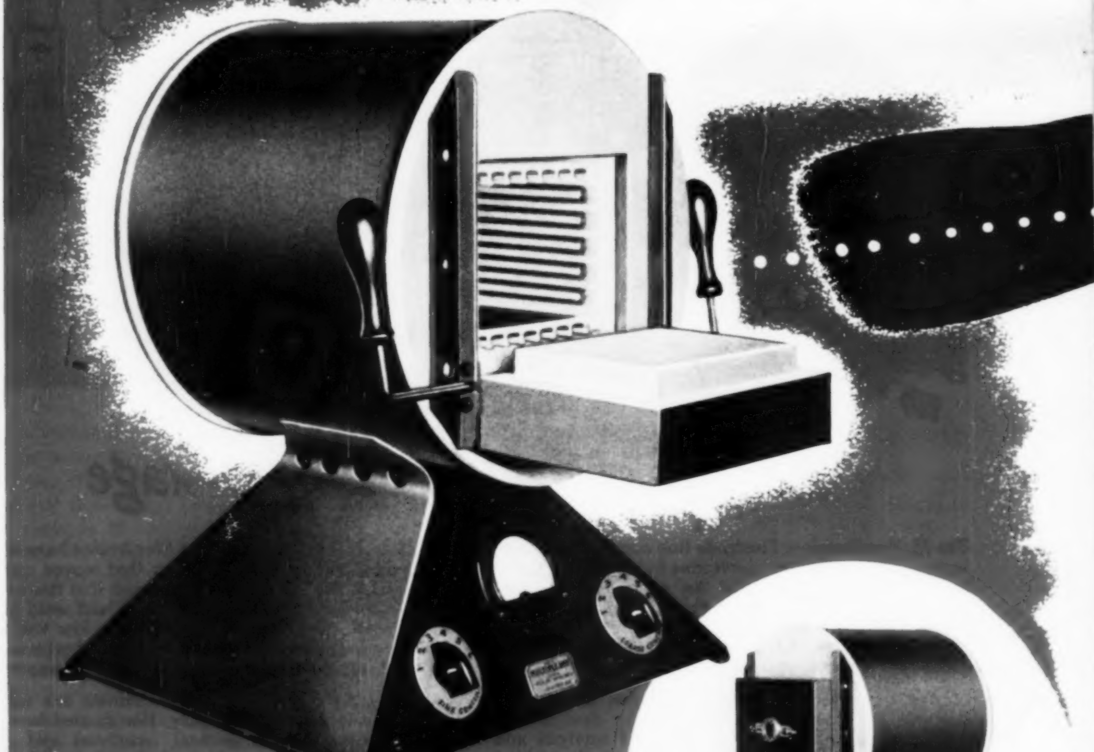
THE McKAY COMPANY
403 McKAY BUILDING
Pittsburgh, Pa.
Sales Offices: York, Pa.

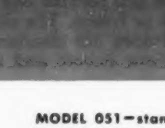
McKAY STAINLESS STEEL · MILD STEEL · ALLOY STEEL · WELDING ELECTRODES

Researched, Developed and Manufactured to fill Industry's Requirements for Dependable Electrodes

HEVI DUTY..

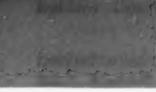


MODEL 051—standard for use on 115v, 50-60 cycles, or 230v, 50-60 cycles, A.C. only. For D.C. current, a separate rheostat can be supplied for temperature control.



Instruments and Controls Operate at Approximately Room Temperature

Minimum contact area between furnace shell and pyramidal support allows free circulation of air . . . eliminates trapped heat.



NEW OLD

Improved Insulation Design with Minimum of Radiation Loss

As a result of correct insulation design, you can shift rapidly to desired operating temperatures . . . from cold to 1850° F. in 65 minutes.

New Design Retains Well-Known Multiple Replaceable Units

For over 30 years, these reversible and easily replaceable multiple units have proved to be the most satisfactory design.

. presents the first of a new design in...

. MUFFLE FURNACES . . . . .

A New Multiple Unit Muffle Furnace Featuring the Greatest Advancement in . . . . . Laboratory Design During the Past Decade

FOR many months, Hevi Duty staff engineers and technicians have been designing, perfecting, and testing a revolutionary new design in Laboratory Furnace construction. Today, these furnaces are coming off the production line, ready for delivery, to set new performance records for you . . . with more efficiency and economy than ever before.

These furnaces have been designed primarily for general laboratory requirements such as drying of precipitates, ash determinations, fusions, ignitions, heating metals and alloys, enameling, heat treating and for experimental test work.

Departing from the usual square or rectangular shape, the new Hevi Duty Muffle Furnace is housed in a cylindrical shell mounted on a pyramidal type base with practically line contact between them . . . allowing for free circulation of air and eliminating trapped heat in the base.

Among many of the outstanding improvements, you will find:

(1) Instruments and controls at approximately room temperature.

(2) Improved insulation design cuts radiation loss.

(3) There are 36 steps of control through a Hevi Duty Tap-Changing Transformer.

(4) Recessed position of controls affords full protection.

(5) Instruments are easily accessible through removable panels.

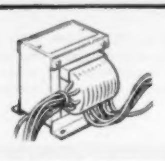
Because the replaceable and reversible Multiple Units have proved so efficient and satisfactory for 30 years, they have been retained in the new design. There are many more features you will want to know about. Send today for the new Hevi Duty Bulletin HD 0141.

For complete details, construction, and specifications... see your Laboratory Supply Dealer.

HEVI DUTY ELECTRIC COMPANY

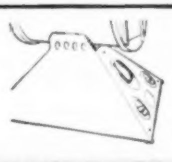
LABORATORY FURNACES **MULTIPLE UNIT** ELECTRIC EXCLUSIVELY

MILWAUKEE 1, WISCONSIN



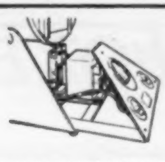
36 Steps of Control Through a Hevi Duty Tap-Changing Transformer

Maximum flexibility of control is assured through ample control steps on a conservatively designed Hevi Duty Transformer.



Recessed Position of Controls Affords Full Protection

Controls are mounted in a recessed position for safety and at the correct angle for proper vision and ease of operation.



Instruments Easily Accessible Through Removable Panels

Rear Panel can be removed for easy access to terminal board. Release of front panel then permits control assembly to slide forward.

WHAT! *no gears... no cables... no fast-moving parts?*

NOT with this electronic potentiometer

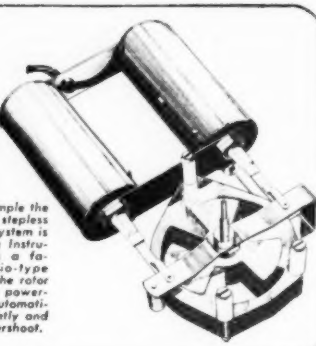
. . . because it has NO SLIDEWIRE

The unique balancing device of Dynalog* Electronic Instruments employs a variable capacitor instead of a slidewire. It is so basically simple that it has only 6 moving parts . . . and only movements of small magnitude are involved. There's nothing to clean, lubricate, adjust, take up or replace. No moving contacts to wear or corrode. Neither dirt, shock, vibration nor ambient temperature can affect its accuracy.

Dynalog balancing is not only continuous but *completely* stepless . . . with sensitivity unlimited by the turn-to-turn steps of slidewire winding. It is so fast that pen or pointer moves full scale to complete balance in as little as 1 second (5 seconds standard).

Dynalog Instruments are available for the measurement and control of temperature (with thermocouples or resistance bulbs), humidity, pressure, flow, force, etc. Complete details in Bulletin 427. Write **The Foxboro Company, 52 Neponset Ave., Foxboro, Mass., U. S. A.**

*Reg. U. S. Pat. Off.



See how simple the continuous, stepless balancing system is on Dynalog Instruments. It's a familiar radio-type capacitor, the rotor of which is power-balanced, automatically, instantly and without overshoot.

OTHER DYNALOG FEATURES

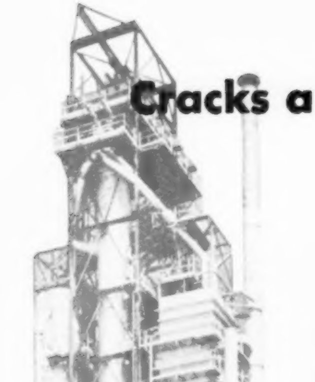
- **SENSITIVITY** . . . *one ten-thousandth of scale (1/100 of 1%)*
- **SPEED** . . . *full scale to complete balance in as little as 1 second (5 seconds standard)*
- **ACCURACY** . . . *1/400 or 1/4 of 1% of scale • No galvanometer • No batteries to standardize • No maintenance except occasional replacement of standard radio tubes • No knowledge of electronics needed*

FOXBORO

Reg. U.S. Pat. Off.

DYNALOG *ELECTRONIC* **INSTRUMENTS**

Metallurgical Recommendation Cracks a Hot-Catalyst Conveyor Problem



This Thermofor catalytic cracking unit plays a vital part in present-day production of high octane gasoline, fuel oil and other petroleum products. Photos courtesy of The Jeffrey Manufacturing Company.

A REPORT FROM
REPUBLIC STEEL'S
Alloy
METALLURGICAL FILES

Picture a 200 ft. vertical conveyor used to maintain catalyst circulation in the Thermofor catalytic cracking process. At a temperature of 900°F., its continuous chain of 9" projection buckets handles more than 100 tons of catalyst per hour . . . must remain in uninterrupted service for periods as long as five months.

Faced with the problem of finding a chain-link material which would afford the necessary strength, heat-resistance and light weight, the manufacturer called in a Republic Field Metallurgist. Working closely with company engineers, he recommended the use of specific alloy steel analyses for side bars, thimbles and pins . . . providing a prompt, economical solution to the problem.

Perhaps you, too, can benefit through Republic Steel's Metallurgical Service. It's available to you at any time without cost or obligation. Write, wire or phone:

REPUBLIC STEEL CORPORATION • Alloy Steel Division, Massillon, Ohio
General Offices, Cleveland 1, Ohio • Export Department: Chrysler Building, New York 17, N. Y.

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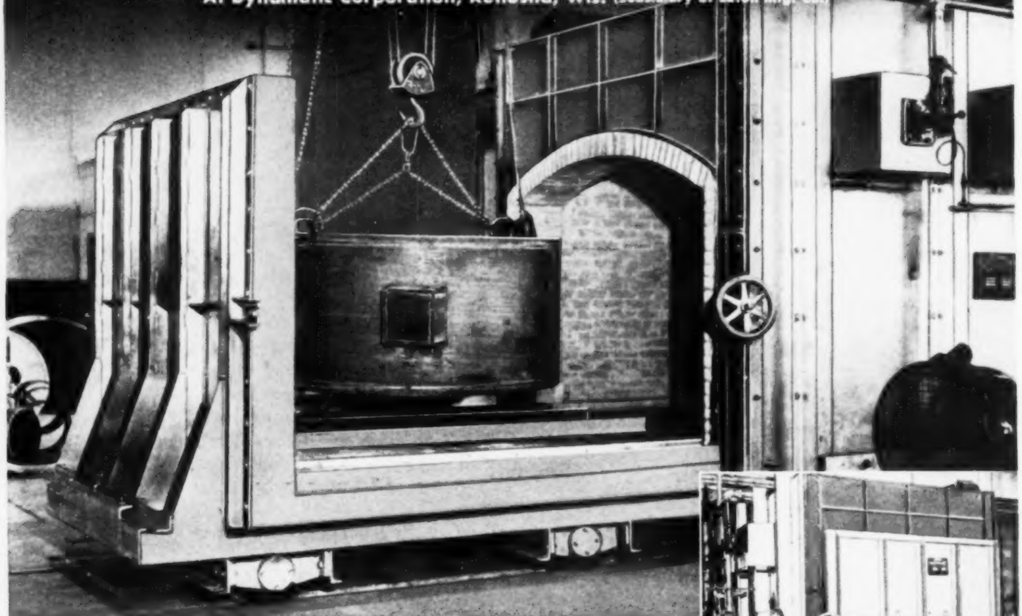

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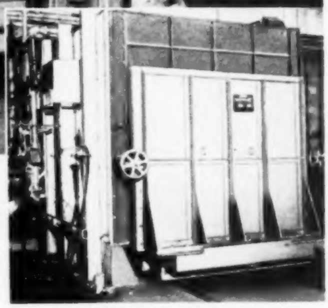

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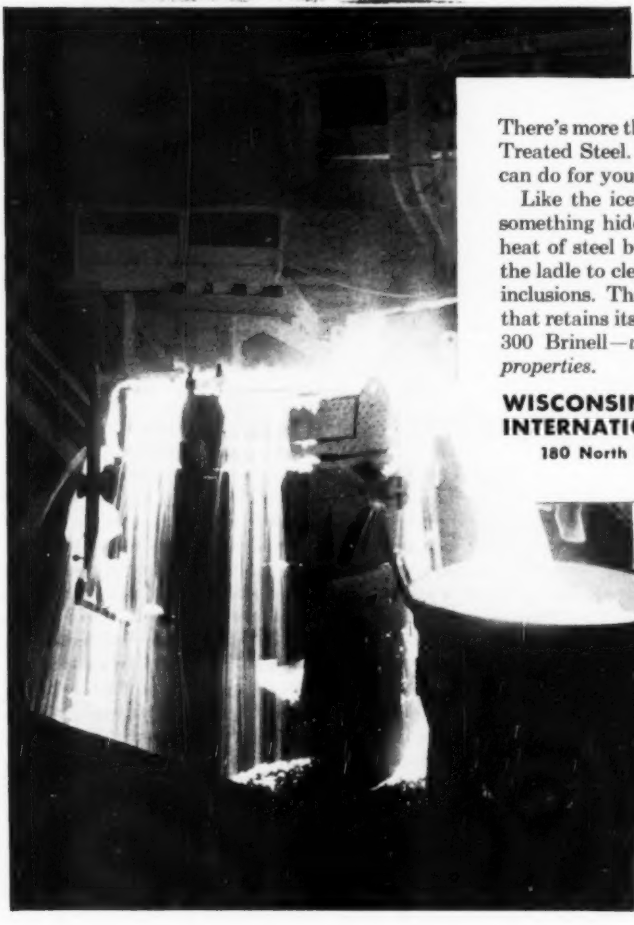

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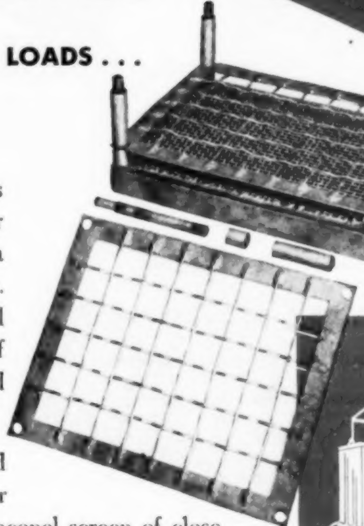

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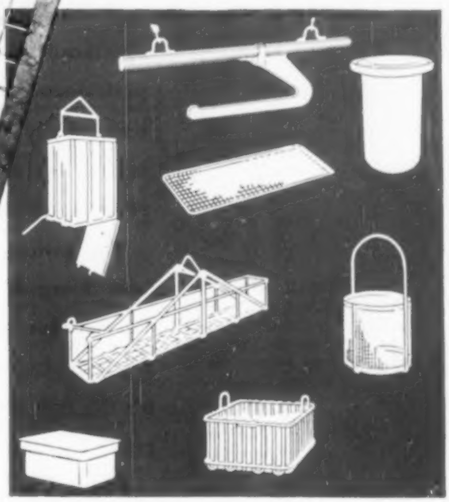

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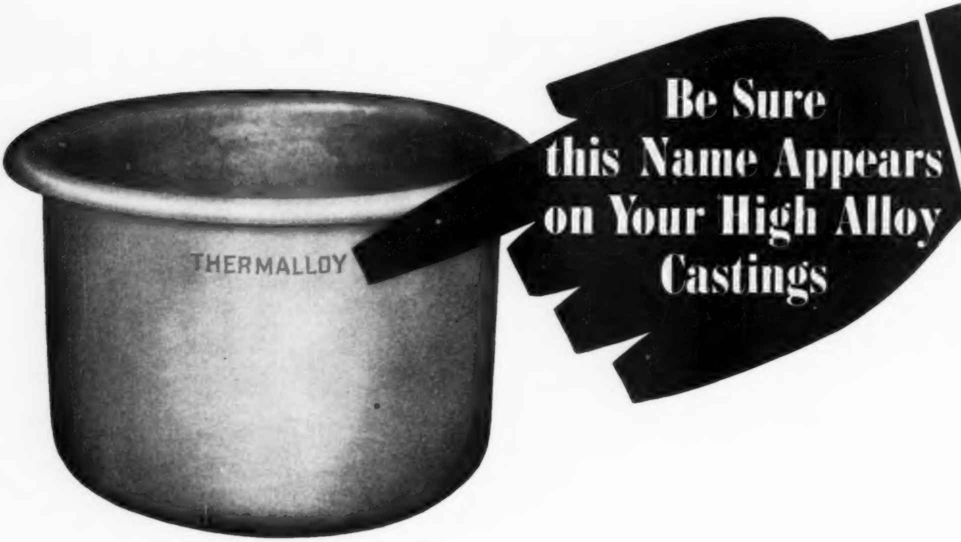

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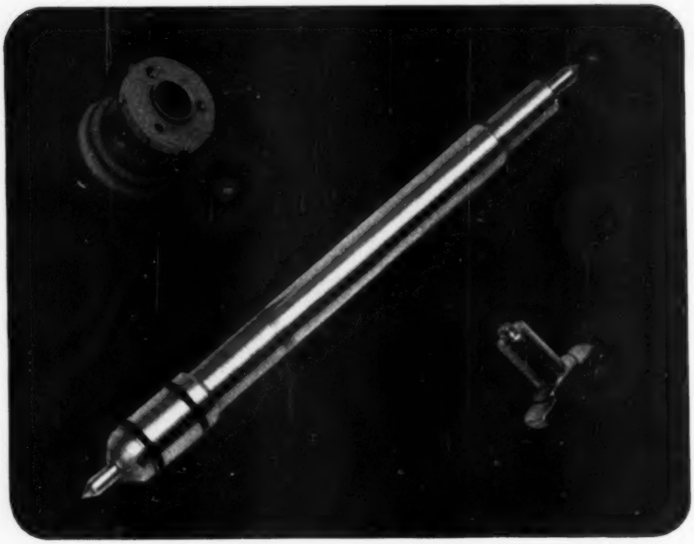

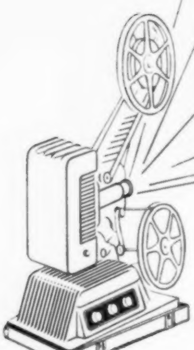

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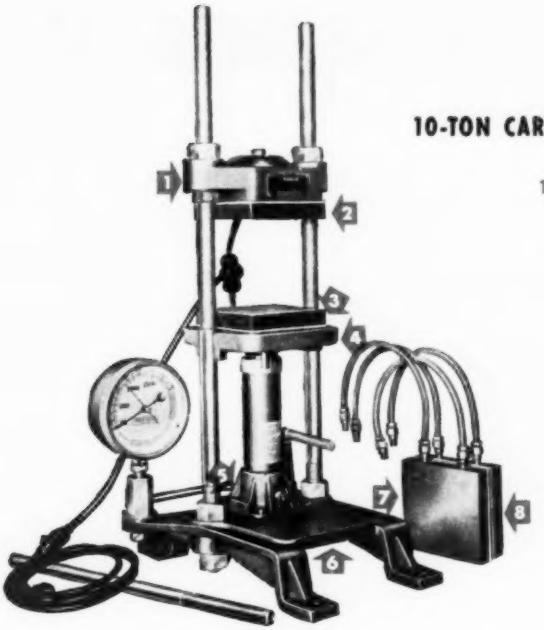

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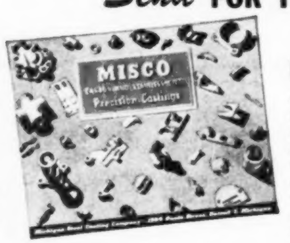

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METAL PROGRESS

Vol. 55 **June, 1949** **No. 6**

Ernest E. Thum, *Editor* Taylor Lyman, *Associate Editor*

Table of Contents

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GAS CARBURIZING

By C. H. Leland
Furnace Engineer
Buick Motor Division, G.M.C.
Flint, Mich.

THE PROBLEM of furnace atmospheres may be divided quite naturally into two categories. One involves the careful study of *fundamental* principles of the process and the assembly of all pertinent data; this includes chemical reactions, rates at which they proceed, chemical potential, surface effects, as well as information about steel properties such as the limits of solubility and diffusion rates. The other and equally important division concerns the *specific* process, the result desired and how that result may be most economically obtained.

In the more limited field of gas carburizing the practicing metallurgist is confronted with the problem of heating a specified number of pieces of certain physical shape in a prepared atmosphere, putting them into and taking them out of a heated chamber. Any gas or mixture of gases surrounding the steel parts may constitute an "atmosphere" — whether it is air, water vapor or any artificially prepared gas — but since our heating and carburizing operation obviously cannot be performed in the simple air medium, we must have an enclosed chamber and a flow of a controlled atmosphere to the chamber sufficient to exclude all of the surrounding air.

Gas carburizing isn't so difficult when the equipment is right and it is operated by a man who knows the simple fundamentals of the process. Anyone else gets into a peck of trouble. Mr. Leland prefers batch-type carburizing for most jobs, especially where less-than-maximum surface carbon is specified. He also diagnoses a few troubles commonly met in the shop and shows how they may be corrected with ease and dispatch.

Commercial atmospheres for heat treatment are somewhat limited as to their composition. Volumes measured in thousands of cubic feet per hour are often required, so prepared gases must be easily made from materials that are readily available and are low in cost. Even with this limitation the total list of gases that may be applied to the work chamber is eight in number — oxygen, nitrogen, water vapor, carbon monoxide, carbon dioxide, hydrogen, ammonia, and a hydrocarbon, of which the most common is methane or propane. If we include the two elements found in steel, namely, carbon and iron, we have a total of ten components, and the number of reactions that can be written from them is enormous. Our problem is to control the conditions in such a way that only the minimum number is involved in the processing.

A simple experiment may point out the No. 1 requirement for control: a completely sealed tube in which iron turnings are in contact with pure carbon monoxide is heated in a furnace to 1500° F. for a few hours. The carbon monoxide breaks down to solid carbon and carbon dioxide according to the "producer gas reaction" $2CO = C + CO_2$. The CO_2 in turn oxidizes the iron to iron oxide in this manner: $CO_2 + Fe = FeO + CO$. Here we start with a pure gas, ordinarily thought of as "reducing" in nature, in contact with steel, and the result is a badly scaled metal and a lot of soot!

To counteract the effect of the producer gas reaction and the damage done to the steel by the CO_2 which is so formed, an effluent tube must be added to the work chamber and the pressure in the chamber maintained by furnishing a continu-

ous flow of a prepared gas. Realizing that the work chamber is at an elevated temperature and that the density of the gases decreases as the temperature increases, precaution is taken to maintain the chamber pressure slightly above atmospheric to avoid contamination by the surrounding air.

Commercial furnaces have a greatly varying degree of "tightness", either when new or after having been in operation for months; many atmosphere furnaces are not tight enough. Batch-type units usually are a great deal tighter than continuous units; consequently no hard and fast rule can be laid down as to the quantity of gas needed or the size of the effluent opening calculated. As a general rule, furnace pressures in excess of 0.2 to 0.3 in. of water column are seldom encountered, and the flow of gas required to maintain this pressure is ample to overcome the deleterious effect of decomposing carbon monoxide. Experience has indicated that a pit furnace 25-in. diameter by 36-in. depth, when supplied with 100 cu.ft. per hr. and a ⅛-in. pipe as an effluent tube, produces a furnace pressure of 0.5-in. water column. A 48-in. diameter by 60-in. depth pit unit requires 250 cu.ft. per hr. with a ½-in. pipe opening. These figures are, of course, only approximate.

It may be well to point out at this time that the fact that a flame is burning at the end of the effluent tube is no positive indication of furnace pressure. Gas may issue from this opening and burn, while at the same time air may be leaking in at the bottom of the unit. A good positive check is to use a standard draft gage.

Ideal Carrier Gas

By the proper choice of a prepared gas we may limit the proportions of three gaseous elements to a very low value: They are oxygen, water vapor, and carbon dioxide. The fourth gas, nitrogen, may be disregarded because of its chemical inactivity.

The ideal carrier gas is prepared from the products of complete combustion of a hydrocarbon fuel from which a large part of the water vapor is removed by condensation, and the CO_2 and balance of water vapor is reduced by hot charcoal. The result is a gas with approximately 20% CO, 1 to 2% H_2 and the balance nitrogen. Dilution of the CO by nitrogen is desirable; the partial pressure of CO in this mixture is about one fifth and at lower partial pressures CO becomes more stable and less likely to soot; also the percentage of CO is high enough to counteract the effect of detectable residual amounts of CO_2 and still be carburizing in nature. (Hot steel would decarburize in a commercially pure nitrogen gas without this action being detected by the ordinary means of gas analysis.)

A somewhat less desirable gas and yet one which is less costly to prepare is made by catalytic cracking of a hydrocarbon gas with air in the presence of nickel compounds at elevated temperatures. If natural gas and air are introduced into such a unit in proportions of 2½ parts of air to one of gas the effluent composition is approximately 20% CO, 40% hydrogen, 40% nitrogen, and a small percentage of methane. This small amount of methane may become very bothersome in the clean hardening of medium carbon steel where no carbon pickup is allowable, or even in some special requirements of carbon control in carburizing cycles.

From thermodynamic data which are available, the equilibrium concentrations may be computed at various partial pressures of the CO-CO_2-C system as well as the CH_4-CH_2-C system. Eliminating the computations (which are available elsewhere) we may state that a 20% CO gas is a very weak carburizer. The equilibrium ratio of CO/CO_2 is large, and any CO_2 formed by the decomposition of CO when it supplies carbon to the steel requires a large amount of CO to re-establish equilibrium. The opposite is true for methane. The ratio of CH_4/H_2 is very small at equilibrium; hence any hydrogen formed by the decomposition of CH_4 requires very little additional methane to re-establish equilibrium. Therefore methane is said to be a very strong carburizer — approximately 1000 times the strength of the 20% CO carrier gas. The problems of gas reactions are thus simplified when we supply a relatively inert 20% CO gas into which is admitted varying quantities of a strong carburizing gas.

Notes on Furnace Operation

The next concern is to get the pieces we wish to carburize into and out of the carburizing chamber without seriously upsetting the condition of the furnace. This single problem is one of primary importance and one that is the chief cause of a lot of operating difficulties. Take for example a batch-type unit of a definite size into which a load is placed, sealed from the air and a supply of carrier gas together with its carburizing component is admitted. The question arises, "When does the unit establish its carburizing potential?"

Here again we have a situation that cannot be governed by any hard and fast rule. One fact is certain — that the atmosphere must have its carburizing potential available *before* the load has reached a temperature where carburization may

take place. Otherwise a great many intermediate or auxiliary reactions will become involved, many of which may be harmful to the steel surfaces. It is well to remember in this connection that the "purge out" time must be faster for thin sections, where the heating is rapid, than for the heavier sections.

Frequent Orsat analyses of the effluent gas should be made at the start of the cycle to observe the rate at which the CO_2 is exhausted from the furnace. We may calculate the rate at which it should mechanically purge out if we know the free volume of the unit, the temperature of the unit and the flow of gas entering the unit, from the equation

$$\log_e \frac{100}{A} = \left(\frac{F}{V}\right)\left(\frac{T_a}{T_g}\right)$$

where A is the percentage of the original volume, F is the flow of gas in cubic feet per hour at temperature T_g, and V is the volume of the unit in cubic feet at temperature T_a.

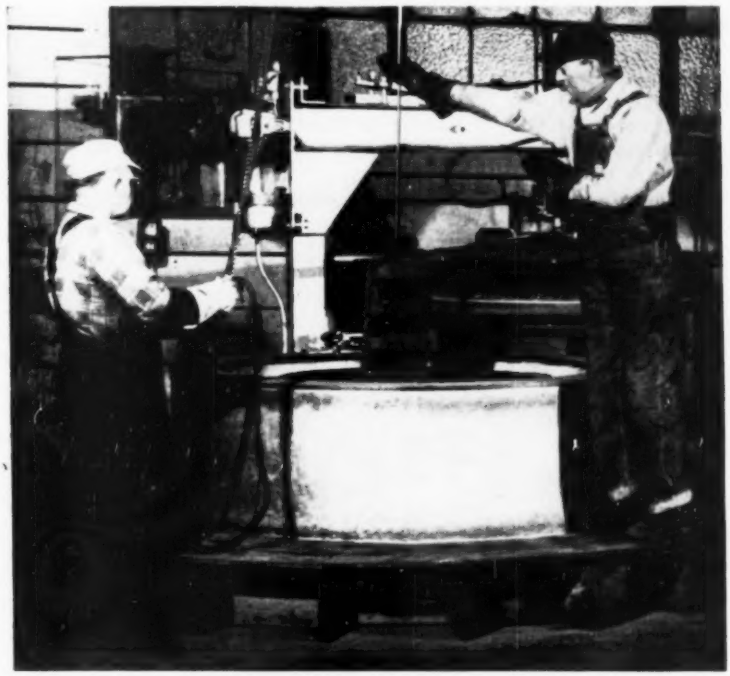
From this equation one may determine the time required to purge the chamber of one-half its original volume, to $\frac{3}{4}$, $\frac{7}{8}$, and so on. If the rate so calculated does not match that indicated by the Orsat analysis within reasonable limits, then we know that the unit is not in proper operating condition.

Generally a new furnace must first be seasoned or conditioned on being placed in operation. To do this a carburizing atmosphere is admitted to the chamber while at temperature and held for a sufficient length of time to allow all air and water vapor to be diffused out of the brickwork, and to reduce all solid oxides that can be reduced by the atmosphere. In practice, after this preliminary conditioning, purge times will be normal (or slightly faster than normal) due to the presence of solid carbon which has been deposited in the chamber during the seasoning. With the furnace in this condition, only an occasional Orsat check is necessary for successful operation.

As frequently happens sooner or later, the unit does not operate as planned; that is, the purge out time is considerably longer than it should be, or it cannot be completely purged to a low value of CO_2. In this event the first item to check is furnace pressure, to be sure there is no air infiltration; second, check the analysis of the gas entering the unit; third, ascertain whether there is a possible water leak from cooling glands or of air being pulled in around a fan shaft; fourth, check for the possibility of solid oxides being admitted to the chamber on scaled stock, and fifth, study the prior history of the unit for events that might give a clue to the difficulties, such as improper maintenance work, too long an exposure of the hot chamber to air, and other unusual circumstances.

In the operation of continuous furnaces we have somewhat similar problems; however, here we wish to maintain an atmosphere undisturbed in the carburizing cham-

Carburizing Oil Well Tools (Courtesy Leeds & Northrup Co.)



ber while pieces are placed into it and removed from it. To accomplish this we must have a satisfactory purge of the loading and unloading vestibules. Consequently the checks mentioned relative to the carburizing chamber also apply to the vestibules.

When all operating conditions are correct we have reduced the chemical reactions in the hot chamber to the decomposition of methane to carbon for the supply component of the process. It would be misleading to specify percentage composition of methane in the incoming carrier gas. The proportion that is right for one application may be greatly in error for another, even though the case depth and carbon concentration may be the same in the carburized parts. In order to intelligently fix the flow of natural gas to a unit, the operator must know the load relative to surface area to be carburized and the case depth required. This will allow him to calculate the pounds of carbon necessary to perform the job.

As an example, assume a load of parts having 200 sq.ft. of surface area to be carburized at 1700° F. to a penetration depth of 0.050 in. With 1.35% C at the surface and 0.20% C at the core, this will require

$$\left(\frac{1.35-0.20}{100}\right)\times\frac{0.050}{2}\times 200\times 144\times 0.28=2.318 \text{ lb. C}$$

One cu.ft. of natural gas at low partial pressure has available approximately 12/380 or 0.0316 lb. of carbon. Therefore the minimum amount of natural gas to be supplied to this job should be 2.318÷0.0316 or 72 cu.ft., allowing no factor of safety. Realizing that *all* of the gas entering the unit does not give *all* of the carbon to the steel, we must supply more than this amount. If the operation requires 4 hr. at temperature it would be advisable to supply between 25 and 30 cu.ft. per hour of natural gas; this would allow a fair factor of safety for the job and yet not produce an excess amount of soot. This figure, together with 100 cu.ft. per hr. of carrier gas, shows a percentage figure of 25 to 30% methane. There are some operations where the methane content may be as high as 60% and others as low as 10%.

Measurement of Case Depth

Over the years there has been quite a discrepancy in case depth terminology. Case depth is most usually measured by the fine grained rim on a hardened and broken specimen, or the bright rim on a hardened and etched cross section. The work of Wells and Mehl has shown that variations in grain size and additions of alloying elements have a negligible effect on the diffusion rates of carbon, even though they do have a pronounced effect on hardenability. Consequently, effective case depth or hardenable case depth is not measured by the carbon concentration at the surface. Since the carburizing process is simply one of adding carbon to steel, it seems advisable to define case depth in terms of carbon concentrations.

One scheme that consistently lends itself to complete analysis is to measure the actual amount of carbon absorbed by the steel. This requires chemical analyses of successive turnings from the surface of a round test sample. The data when collected give

$$\text{Case depth}=\frac{\%\ C\times \text{Inches}}{2\,(\text{Max.}\ \%\ C-\text{Min.}\ \%\ C)}$$

This would be a tedious method for checking shop operations. Another method for shop checks, that approaches the above definition of case depth, is the use of a 1020 test piece carburized with the load, hardened from 1400° F., cut and etched with a 50% HNO_3 acid solution. When the total darkened area is measured, the depths reported will agree within 0.005 in. of those shown by chemical analysis.

From an extensive group of tests using a large variety of commercial carburizing steels we have postulated a formula which has been found very useful:

$$\begin{aligned}\text{Case depth of } 1700^\circ\text{ F.} &= 0.025\sqrt{T}\\ 1650^\circ\text{ F.} &= 0.021\sqrt{T}\\ 1600^\circ\text{ F.} &= 0.018\sqrt{T}\end{aligned}$$

where T = time in hours

Needless to say, this formula is only applicable when a full carburizing gas is employed.

Maximum Carbon at Surface

A great deal has been written during the past few years on the subject of carbon concentration control. One school of thought postulates a gas supply that is in equilibrium with the desired surface concentration level. A critical study of the thermodynamic properties of the two gas systems CO-CO_2-C and CH_4-H_2-C, together with the water gas reaction, will show the extreme care that must be exercised to achieve this result. Shop practice does not have, as yet, the finesse with which to handle such a delicate job. Then too, the carburizing time is frequently prolonged considerably with a weaker gas system.

In batch-type work we deem it advisable to make full use of the chemically inert carrier gas during a diffusion period following the carburizing period. This is a very simple operation; merely discontinue the supply of carburizing gas at the time the total amount of carbon has been absorbed

by the steel, and hold the load at temperature to allow the surface carbon to diffuse to any desired lower level. This process may be adapted to almost any specification desired, from deep cases of high concentration to shallow cases of low concentration — or any intermediate combination of the two.

Carbon control in a continuous furnace is more difficult with present-day equipment. Some attempt it by admitting the carburizing gas in the front end of the furnace, and also reducing the temperature at the discharge end. In this manner surface concentrations as low as 1.00% C may be obtained.

Carbon restoration on surface decarburized parts is another example where the 20% CO carrier gas is valuable. Remembering that carbon will flow from a higher concentration to a lower one at elevated temperatures we need simply to heat the parts in this neutral atmosphere to allow the carbon from the interior of the metal to replace that which has been lost from the surface. Extremely badly decarburized parts may require the addition of carbon to the surface from the exterior. This can be accomplished by admitting carburizing gas for a short period, followed with a diffusion period to allow the carbon to fill in the valley.

Difficulty is experienced at times in obtaining uniformity of case depth. This is especially true in batch-type units that are very densely loaded. When properly analyzed this variation can be caused by only two factors — *(a)* nonuniformity of heating and *(b)* inability to circulate the gases through the load. Both of these factors are parallel, for if you are able to circulate the gases through the load the temperature will be uniform.

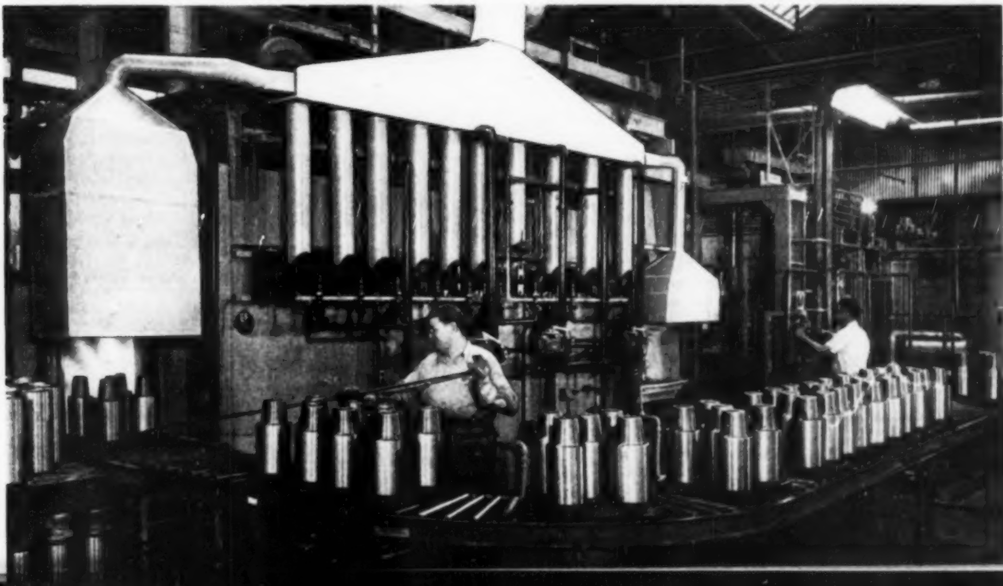
In batch-type work the furnace must have a very efficient fan as well as control of the heating rate. A good practice to observe is to slow down the rate of heating when the charge is 100 or 150° below the final temperature, to allow all parts of the load to reach the temperature at the same time. In other words, operate the batch unit similar to a two-zone continuous furnace wherein the majority of heat is supplied at a fast rate in the first zone and a small amount of heat is supplied in the temperature-attainment zone. Satisfactory operation is obtained in pit-type furnaces to allow 100% heat input up to 1550° F., and then cut to 35% heat input up to 1700° F. This may be done automatically through an input controller in conjunction with a temperature controller. This, together with a high-efficiency fan of the impeller-propeller type, gives uniform case depths throughout a load density of 35%.

Summary of Essentials

The fundamentals of gas carburizing may be summarized by a few statements:

1. Employ a gas such that all chemical reactions take place outside the carburizing chamber except the one that supplies carbon to the steel.
2. Employ sufficient carburizing gas to make sure of meeting the requirements of maximum carburizing rate.
3. Do not use enough carburizing gas to cause excessive sooting in the furnace.
4. Provide for uniform heating.

Gas-Fired, Radiant-Tube Continuous Furnace for Gas Carburizing (Courtesy Electric Furnace Co.)



A New Approach to Atomic Control*

IT WILL be remembered† that the debate on atomic energy had been placed on the agenda of the General Assembly of the United Nations which met in Paris last fall. In the ensuing debate it was soon evident that, although the great majority of the nations represented were not ready to support the Soviet contentions that the Commission's prior efforts had achieved no substantial results, or had ignored its mandate, they would nonetheless be reluctant to suspend efforts to solve the problem.

It decided that the time was not ripe to attempt to formulate a treaty for atomic control (since the U.S.S.R. would not participate in its elaboration), nor to start all over again a discussion which had to some extent added to the international difficulties of the last two years. The text of the instructions eventually adopted by the General Assembly instructs the Commission to "proceed to the further study of such of the subjects remaining in the program of work as it considers to be practicable and useful".

A further point hotly debated in Paris was whether or not the commitments on prohibition and control would have to come into force simultaneously. A "concession" was offered by Mr. Vishinsky, that these should be simultaneous. For the Assembly the question was whether such a proposal offered a useful basis for resuming work by the Commission.

There are, it seems, some good reasons for answering this question in the negative. First, it brought nothing new as far as the methods by which an effective international control could be set up. Then, it completely ignored the idea that there should be some stages in the establishment of such control. Finally, if it is true (as the majority believes) that the idea of stages could not be dropped without dropping the political and technical guarantees indispensable to the success of the whole scheme, the Soviet proposal still amounted to asking for the destruction of atomic weapons before the Agency could guarantee that the machinery of safeguards was in full operation.

To sum it up, the debate in the General Assembly has not brought a solution any nearer either on the political plane or at the level of the control machinery. When we examine this discussion, there seems to be little reason for rejoicing.

Yet a new fact has been created from which we must try to extract all the good that is possible. The Assembly's resolution recommends first that there should be consultations among the six permanent members of the Commission. In spite of the unfavorable Soviet reaction, it seems that this might offer a new line of approach to the problem which has baffled our efforts for the last two years.

The U. N. Atomic Energy Commission, in its past examination of the problem, has worked *upward* from the technical evidence to the complete set of safeguards which are embodied in the Second Report.‡ The Soviet representatives have rejected the results of this procedure, and objected to the procedure itself. Would it be helpful to try the alternative approach of working *downward* from broad principles to the details of application?

Here is one example of what I have in mind: The Russians have always said that the right to conduct air surveys was quite unacceptable to them. Would it not be useful to ask them whether they agree that there can be no security if nations can permanently seal off certain parts of their territories from international inspection?

The whole philosophy of the majority plan could probably be reduced to no more than five or six principles of this kind, for which the evidence has been gathered. I know that the Soviet Government might be even more reluctant to discuss broad principles than specific proposals. But it could also be argued that the past failure of our work compels us to think anew, and that if we fail again we will at least have shown some ingenuity in our methods and consistency in our purpose.

Second, there are some possibilities in following the General Assembly's recommendation that the Commission re-examine its remaining program. Such items have been adjudged (by the Commission) as dependent either on an agreement on the methods of control or on "the conditions of world security", that is to say, that they must be part of a political settlement.

This leaves one possible course for the U. N. Atomic Energy Commission: To tackle the dreaded political problems of the stages of the transition from national to international control and of the principles governing the geographical locations of dangerous activities and facilities.

The latter question — the question of quotas — is the only part of the majority proposal which has been referred to in sympathetic words by Mr. Vishinsky. Would it not be wise to ask the Russians to submit some precise proposals on this particular problem?

No one could exaggerate the difficulties of these problems nor even the risks attached to examining them in public. All these are matters to be pondered over by governments. Clearly, it was the political questions which were in everyone's mind at Paris, and these will reappear in 1949 in the same form unless the Commission can reflect the results of fruitful thinking in the interval.

*Extracts from an article in *Bulletin* of the Atomic Scientists, Jan. 1949, p. 9, by Francois de Rose, French representative on United Nations Atomic Energy Commission.

†See *Metal Progress*, Dec. 1948, p. 843.

‡See *Metal Progress*, Jan. 1947, p. 89.

Presentation of verbatim extracts from important contemporary documents concerning atomic energy does not imply that the Editor agrees with the opinions quoted, nor that they are expressions of A.S.M. policy.

NITROGEN DEGASSING OF NONFERROUS METALS

By T. W. Eselgroth
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ALL molten metals will dissolve objectionable gases such as hydrogen, oxygen, carbon dioxide, carbon monoxide and sulphur dioxide. These gases are dissolved in various quantities, affinity for hydrogen generally being greatest. The solubility of hydrogen increases as the temperature of the metal is increased and, in some metals, there is an appreciable increase in the solubility during melting. During solidification the gas is released from solution, but a portion is entrapped in the solidifying metal and causes minute gas occlusions, usually referred to as pin-hole porosity. This would be eliminated if all gases were inert, or if melting and casting could be done in a vacuum. Although these ideas are impractical for most foundries, we can take advantage of the fact that nitrogen, a relatively inert gas, will not dissolve in aluminum, copper, or alloys of these metals. Flushing these metals with nitrogen will remove hydrogen and other absorbed gases which cause porosity. The absorbed gases will diffuse into the rising nitrogen gas bubbles, and will be carried off.

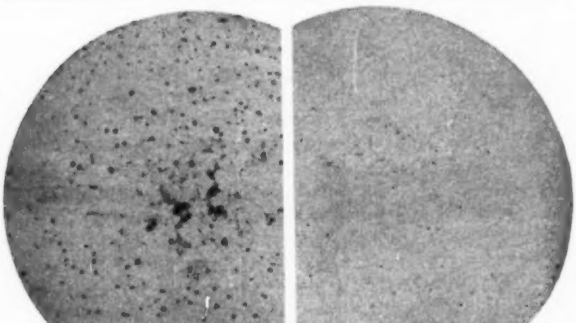


Fig. 1 — (Left) Aluminum Ingot Poured From a Melt That Was Purposely Gassed With Hydrogen to the Saturation Point. (Right) Aluminum ingot poured from the same heat, but after degassing with nitrogen. Reduced to ¾ size

In Fig. 1 (left) is shown a cross section of an aluminum ingot poured from a melt purposely gassed with hydrogen to the saturation point. A great many small, well-defined voids can readily be seen. The cross section of the aluminum ingot shown at the right in Fig. 1 was poured from the same heat, but after the molten alloy had been degassed with nitrogen. As can easily be seen, the porosity caused by the hydrogen, purposely dissolved in the melt, and any other gases that might have been present, has been removed by the degassing treatment.

By simply bubbling nitrogen through the molten metal, oxides were aided in reaching the top, where they were entrapped in the dross. Under appreciable pressure, the dissolved gases diffused through the gas-metal interface into the rising nitrogen gas bubble. This physical reaction continued until the partial pressures of the gases were in equilibrium, or nearly so.

Nitrogen degassing is not the only method used to degas molten metal. Some foundries allow their metal to cool slowly and then rapidly reheat it to the desired pouring temperature. However, slow solidification is time consuming, and there is no assurance that gases will not be picked up during subsequent remelting. Small foundries have been using solid fluxes to remove gas. This method usually leads to other defects because some fluxes produce undesirable inclusions in the melt. Too much depends on the operator, on quantity of flux added, method of application, and agitation technique for this method to be used with consistent success. Degasification by chlorination requires rigid control and adequate health safeguards. Chlorine is toxic, corrosive, and will remove magnesium, a fact which is objectionable in some alloys.

Nitrogen degassing has many advantages over other methods for flushing nonferrous metals.

1. Nitrogen is easier and safer to handle than chlorine and more readily available.
2. It is nontoxic and noncorrosive.
3. It is less expensive than other inert gases, such as helium and argon.
4. Nitrogen degassing, in contrast to the use of solid fluxes, does not decrease the electrical and thermal conductivity of the treated metal.
5. There are no undesirable inclusions in the metal after it solidifies.
6. Nitrogen does a more thorough job of degassing and is often less expensive to use. In some instances, production costs are cut, since degreasing and de-oiling operations are eliminated.

Generally, the metal received from the supplier is free from gases. During subsequent meltdown, porosity-forming gases can be picked up in a number of ways. Porous castings can result from the fuel, from moisture in the atmosphere, and from dissociation of hydrocarbons in the crucible. Porous castings can also result from poor foundry techniques. When poor foundry techniques are followed, porosity will exist in selective areas of a casting. Porosity caused by excessively damp sand in the mold, inadequate venting, hard ramming, inadequate risers, and poor gating cannot be offset by degassing.

The procedure for nitrogen degassing is simple and the apparatus relatively inexpensive. Nitrogen is injected into the bottom of the melt through a suitable tube. Tubing made from steel, cast iron, malleable iron, or graphite will give satisfactory results for degassing aluminum and aluminum alloys. Graphite must be used in copper and copper alloys. The accompanying illustrations show the equipment and procedure used for degassing.

In Fig. 2 the graphite tube, 2-in. diameter, has a porous graphite bulb on the bottom end. The bulb gives better gas dispersion because a multiplicity of small gas bubbles are formed into which the hydrogen will diffuse. Another tube, not shown here, has holes drilled over the bottom; a further adaptation has a porous graphite plug inserted at the bottom end of the tube.

The graphite tube shown in Fig. 3 is being applied to a gas-fired pit-type furnace used for melting brass. Any type of furnace can be degassed effectively. This includes reverberatory, pit, induction, and rotary types. All the apparatus required for degassing nonferrous metals is illustrated. In the center background of the picture is the cylinder of high-purity dry nitrogen to which is attached a regulator. Directly connected to this is a flowmeter, the hose, and the degassing tube assembly.

Figure 4 shows a one-ton heat of copper being degassed in a Schwartz-type furnace by inserting the preheated graphite tube into the pouring spout of the furnace. The fuel has been turned off but hydrogen, flushed out of the melt by the nitrogen, can be seen burning at the spout and charging hole. Five or six minutes is all the time required to remove the entrapped hydrogen effectively. After hydrogen evolution has ceased and degassing is about complete, the metal is transferred to a bull ladle. It is possible to degas molten copper in the bull ladle.

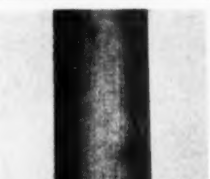


Fig. 2—Graphite Tube With Porous Graphite Bulb for Introducing Nitrogen Into Molten Metal

In Fig. 5 the standard graphite degassing tube is about to be lowered into a pit-type furnace containing approximately 500 lb. of aluminum. First, the tube was laid on top of the pot for several minutes to drive off any adsorbed moisture. It is not necessary to shut off the fuel here as it does not come in contact with the melt. The tube is connected by a hose to the flowmeter in the background. The flowmeter is connected directly to a nitrogen pipe line supply system. Aluminum can be degassed at a temperature as low as 50° F. below pouring temperature, because agitation will raise the temperature as the cooler mass comes in contact with the metal.

Fig. 3 — Nitrogen Degassing of Brass in a Gas-Fired Pit Furnace

Fig. 4 — Degassing of Copper in a Schwartz-Type Furnace

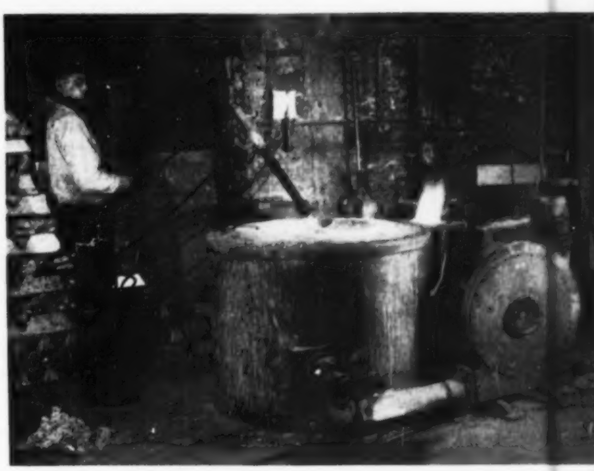


Fig. 5 (Above) — Degassing Tube About to Be Lowered Into Pit Furnace Containing 500 Lb. of Aluminum

Fig. 6 (Below) — Close-up of Degassing of Aluminum. Slow bubbling of gas is continued 10 or 12 min. for this melt.

A close-up of the melt (Fig. 6) shows the slow roll or bubbling of the gas evolving from the surface of the aluminum. Nitrogen is injected at a rate to produce a slow roll permitting the gas to escape through the porous oxide membrane, but not fast enough to cause splashing and subsequent oxide formation or wet dross. The tube can be weighted and left unattended during the degassing period, which is from 10 to 12 min. for this melt.

Degassing tests have been made on a great many alloys of aluminum and copper as well as commercially pure metals. Some tests have been conducted under laboratory supervision and others were made in the field on actual shop specimens. Some tests under laboratory control were made in the field on metals saturated with soluble, porosity-forming gases (hydrogen and carbon dioxide). Specimens were taken at intervals, making it possible to determine proper procedures and flushing gas requirements. Dry nitrogen was used in varying quantities and different flow rates.

The tests revealed that the minimum quantity

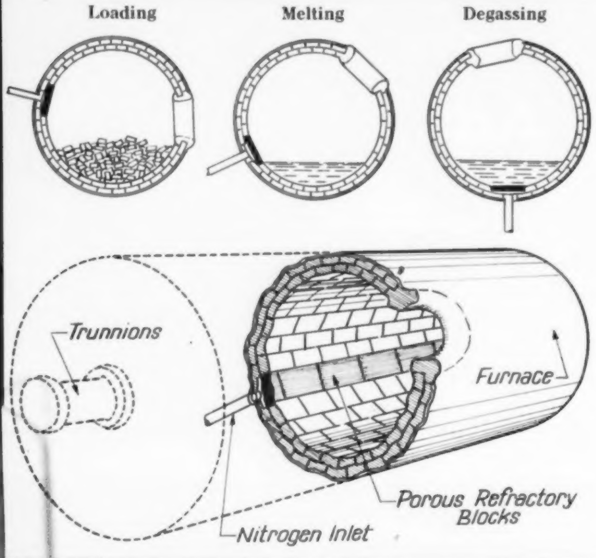


Fig. 7 — Setup Proposed for Degassing a Rotary Furnace

of nitrogen required for aluminum and its alloys is 25 cu.ft. per ton of metal. Copper and copper alloys require a minimum of 8 cu.ft. per ton of metal. Although with good shop practice melts may not necessarily be saturated with porosity-forming gases, the efficiency of the flushing gas drops off with a lowering in the percentage of dissolved gas. Consequently the major portion of the dissolved gas is removed with the first portion of flushing gas, but a complete degassing cycle is required to remove the residual occluded gas.

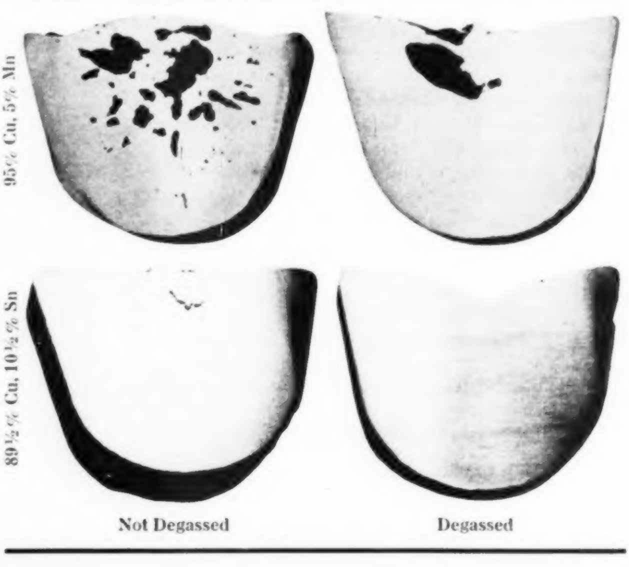
The depth of the melt has considerable bearing on the rate of injection and efficiency of the flushing gas. Generally, the deeper the bath of metal, the more rapidly the nitrogen can be injected and the more hydrogen will be removed per volume of nitrogen. The rotary direct-fired furnace presents a problem for degassing because of the shallow bath. It has been proposed to solve this problem by the method shown in Fig. 7. Here an arrangement of porous refractory material is used in a line that will permit nitrogen gas to bubble through the melt when the furnace is rotated so as to bring the porous material to the bottom. The porous refractory need not run the entire length; two or more locations should suffice.

The use of nitrogen degassing is not new. Both water-pumped and oil-pumped nitrogen operations have been widely used. However, each of these is a potential source of hydrogen because water vapor or hydrocarbons may be present; high-purity dry nitrogen supplied from a cylinder is better. In making some aluminum alloy castings, solid fluxes have been used in combination with nitrogen.

Recent developments for treating nonferrous metals include a vibratory-type dispenser for degassing aluminum that is to be rolled into foil; oxide-free aluminum is essential for foil. Another fluidizing-type dispenser was developed for removing magnesium from secondary aluminum. Additional explorations are being made along these lines at the present time.

Degassing is not a cure-all for foundry troubles. It is, however, an effective tool that will eliminate one source of unsoundness in castings. Complete isolation of the melt from sources of hydrogen and other gases is not practical. However, when correct foundry techniques are followed, nitrogen degassing will:

1. Improve the mechanical, electrical and thermal properties of copper or copper alloys such as brass and bronze.
2. Improve the mechanical properties of aluminum and aluminum alloys.
3. Permit good castings to be made from copper-base scrap returns, chips, trimmings, risers, or sprues, without previous sorting or degreasing operations.
4. Result in cleaner metal as the end product.
5. Impart a more uniform pouring temperature to the molten metal being cast. This feature is sometimes of major importance.



THE USE OF METALS AT LOW TEMPERATURE

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For many years it has been known that steel is more apt to fail at low temperatures than the usual tests would indicate was likely. This was observed in the early days of bessemer steel and was a major factor in the preference for openhearth steel. More recently it has been learned that there is a considerable variation in the low-temperature behavior of ferritic steels generally, even openhearth or electric-furnace steels, and an object of this paper is to discuss the factors which control such behavior.

At the same time it has been learned that many common nonferrous metals suffer no such deterioration, at least not down to liquid air temperatures. Important examples are the pure metals, copper, nickel, and aluminum, and their simple solid solution alloys; the stable austenitic 18-8 Cr-Ni type of alloy falls in the same group. Other metals have been studied at low temperature, especially for research purposes, and there is also interest in the subzero properties of weld metal, solder and brazing metal.

Classification of Low-Temperature Materials— There seems to be a valid and useful differentiation between metals which are sensitive to low temperatures and those which are not, at least for all practical purposes. Typical representatives of each group have been given, but to draw the dividing line would be much more difficult. The ferritic steels can be vastly improved, on one hand, while alloys of the insensitive metals may have relatively poor low-temperature properties. It will be helpful to consider examples of each type.

The common low-carbon steels are clearly recognized as being temperature sensitive. According to the meaning of that term as used here, a part or structure made of such a steel becomes vulnerable to stresses at some low temperature, though at room temperature (approximately) it could withstand the same stresses without failing. This vulnerability may appear sharply at a rather well-defined temperature or more gradually over a range of temperatures, but tests at a higher temperature fail to disclose the structural weakness at the lower temperature.

The insensitive metals behave at low temperatures the same as at room temperature, even if their strength and ductility values may be somewhat different. In brief, if they are good materials at room temperature they remain good materials at low temperatures.

The ductile insensitive metals offer no special metallurgical problem when used at low temperatures. One would employ the usual engineering properties for design and for acceptance and, if the design is right, the part or structure should be suitable for low-temperature service. Whether or not to use the somewhat modified properties would be left to the designer; if he designs on the basis of room-temperature properties, the increased strength at the low temperature would give an added factor of safety. Incidentally, the practice of requiring notched-bar tests of materials of this group has no recognizable justification; this matter will be discussed subsequently.

The brittle insensitive metals also offer no special metallurgical problem. They should be treated as brittle materials, whatever the operating temperature may be.

The ferritic steels, on the other hand, introduce some very real problems of low-temperature behavior which need careful study and analysis. This situation may be recognized in the behavior

of actual structures but these effects are more clearly brought out by comparing tension, torsion, and notched-bar tests at low temperatures.

If we test a structural steel by the tension test at lower and lower temperatures, we find, at first, that it changes relatively little in properties and remains ductile, though if we go low enough, the test bar will break suddenly with but very little ductility. We might be inclined to assume that the steel became brittle at that temperature, but if we test that same steel by a torsion test, we see that it remains ductile right down through that temperature. This must be due to the difference in the stress systems of the tension test and the torsion test.

A more striking example of the effect of the stress system is obtained by testing the steel in a notched-bar test. Due to the geometry of this test bar, the stress which tends to cleave or fracture the bar at the notch is considerably exaggerated in relation to the shear stress which deforms the bar. The result is that the temperature at which the notched bar first develops brittleness is higher than it is in the tension test. The important point here is that a part or structure is frequently subjected to loading which produces the stress system characterized by the notched bar so that it too is likely to fail in a brittle manner ("low-temperature brittleness") even though the tension test would suggest that the steel had adequate strength and ductility.

The classification of steel as temperature sensitive brings out its unique position but before taking up methods of protecting against low-temperature brittleness, let us consider the factors that affect or control this behavior of steel.

Metallurgical Factors of Low-Temperature Brittleness

Without attempting to follow any order of importance, the factors which are recognized as affecting low-temperature brittleness of steel are:

1. The basic elements in steel — carbon, manganese and silicon
2. Impurity elements — phosphorus, sulphur, nitrogen, oxygen, etc.
3. Alloying elements — nickel, chromium, molybdenum, copper, etc.
4. The deoxidation elements — manganese, silicon, aluminum, etc.
5. The actual ferritic grain size
6. The McQuaid-Ehn grain size, though this may simply reflect other factors
7. The austenitic grain size
8. The microstructure, particularly the size and distribution of carbide or other precipitate, as distinguished from the grain size of the matrix
9. Cold working, or cold working plus aging.

As secondary factors, which are frequently of more direct interest, the following may be listed in addition to the composition of the steel: *(a)* steel manufacturing process, *(b)* melting and deoxidation practice, *(c)* rolling practice and finishing temperature, *(d)* condition in which the steel is used (as-rolled, normalized, annealed, or quenched and tempered), *(e)* specific effects such as strain aging, temper brittleness, precipitation hardening, or overheating. It is thought that the secondary factors exert their influence through one or more of the primary factors.

An idea of the potency of these effects may be given by comparing the variability in the embrittling temperature as shown by a standard notched-bar test. Thus ordinary bessemer steel, which is ductile in the tension test or in simple bending, is usually brittle in a notched-bar test at room temperature or even above. At the other end of the scale is a low-alloy ferritic steel which is made to fine grain practice, liquid quenched, and tempered at 1000 to 1200° F. In the same notched-bar test, it may still retain an effective degree of ductility down to −300 °F. Thus the nickel-molybdenum steel A4815 is reported to show 25 ft-lb. at −310° F. with the V-notch Charpy bar, when fully quenched and tempered. The new low-carbon 8½% nickel steel 2815 is likewise reported to remain notch tough at these low temperatures, at least in tests.

Between these extremes, there is an almost continuous gradation of steels with respect to this behavior. Since there is no point in using any better steel than is needed — and it usually costs money to lower the temperature region of ductile behavior — there is a definite question of economics in the selection of the steel and whether to use it as rolled or as forged, or to give it a beneficiating heat treatment. With the introduction of welded fabrication, more attention is being given to the selection of steel composition and manufacturing practice to insure satisfactory performance. These principles are becoming recognized, although as pointed out above, there are also mechanical factors which affect service performance where brittleness of normally ductile steels is the important hazard.

Mechanical Factors of Low-Temperature Brittleness

The selection of steel for low-temperature service can have no precise significance unless certain mechanical factors of the use are also taken into account. We have already seen in principle that the validity of using a given steel depends on the stress system to which it is

exposed; thus torsion is relatively harmless, uniaxial tension is somewhat more critical, and the conditions of stress at a notch are particularly critical. The "notch effect" requires special attention.

The notch effect consists of two factors — a stress concentration across the base of the notch, and a three-dimensional stress system which is due to the rigidity imposed by the general notch geometry. By decreasing the notch radius, the "brittle temperature" is made to occur at higher temperatures, while increasing the width of the bar does about the same thing. These effects are more pronounced with the more notch-brittle steels. Various combinations of stress concentration and the principal or normal stress will doubtless produce various effects on a steel, and it would help if we could treat these two components of the notch effect quantitatively, both individually and in combination. The energy value of the test, or other criterion, gives only the summation of these effects during deformation and fracture and then only for the test bar used.

The major problems in the application of metals for low-temperature service involve ferritic steels. Subzero temperatures raise no particular problems in the metallurgy of ductile nonferrous metals, but recent arbitrary specification requirements for impact resistance threaten to restrict the use of these metals unnecessarily. The author discusses both metallurgical and mechanical factors that enter into the selection of metals for use at low temperature, with emphasis on ferritic steels.

A second mechanical factor is size, as shown by the common experience that large parts or structures are more apt to fail than smaller parts or structures under presumably the same conditions. One very obvious reason is that large parts are more difficult to produce with a fine structure and good metallurgical quality than small parts. This difference shows up readily enough if test samples are taken from a large mass of steel and compared with samples of the same steel properly worked down to a small size. But in addition to this there is an effect of size which predisposes large structures to be especially vulnerable to low temperatures. This holds for rigid structures even though they are built up of small parts. This straight mechanical effect of size is largely out of the metallurgist's hands; however, he should be aware of it and he should be prepared to provide steel with greater notch toughness for a large, rigid structure than would be needed for a smaller, less rigid structure.

Of course, design becomes more critical with the larger structures and much can be accomplished if the effects of stress concentration and rigidity can be reduced. An example of this was given by the hatch-corner tests carried out at the University of California.* Without changing the size but by altering the design to give a streamline stress flow, the breaking stress of the hatch corner was greatly increased to about the strength of a small test coupon.

The size effect is also pertinent to the problem of building a model to study the behavior of the full-size structure. Here one should intentionally use steel of lower quality for the model.

A third mechanical factor is the speed of deformation or the rate of applying the load, though at the lower velocities it operates by raising the strength level of the metal and might better be called a metallurgical factor. Here again the picture is rather complex.

The clearest illustration of the effect of speed is at the "match point" when the ratio of the normal stress to the principal shear stress is the same as the ratio of the technical cohesive strength to the shear strength. It is at this point that the notched bar is ductile in static tests but brittle in impact. Another demonstration is the DeForest test, which determines the temperatures, with constant rates of loading, at which the brittle fracture is first produced. The test shows that the brittle temperature is raised by increasing the rate of loading. In other words, for simple brittle behavior, by increasing the speed of deformation the match point is raised to higher temperatures. Hollomon related velocities to the temperature at which the metal breaks brittlely, and that seems to be the relationship rather than to ductile versus brittle fracture at constant temperature.

For the ductile type of break at higher temperatures, work on the effect of velocity has not led to generalizations of the type just mentioned. However, from the evidence at hand that high speed or impact loading gives greater energy values than static loading, it may be assumed that, within limits, the speed effects of shock loading

*"Tests of Various Designs of Welded Hatch Corners for Ships", by E. P. DeGarmo, *Welding Journal*, Research Supplement, February 1948, p. 50s-68s.

are not significant. With ballistic velocities the situation is different, but such velocities are not considered here.

For low-temperature applications the practical significance of the effects of these mechanical factors is that the steel or the design, or both, should provide for the factor of notch toughness — that is, with the steel used, the design should be in the direction away from the critically dangerous match point condition.

Selection of Steels for Low-Temperature Service

A more accurate title for this section would be "The Selection of Steel for a Given Design for Low-Temperature Service". Except for relatively simple shapes, the selection depends on the size and design of the part or structure, the size of the parts of which the structure is composed, and the service temperature and stress conditions. Thus, there is urgent need for close cooperation between the metallurgist and the engineer. Each one has factors under his control which determine success or failure of the structure in service; furthermore, each can undo the good work of the other, and the most economical solution always comes from the combined efforts of the two.

It has been mentioned that neither the basic steel properties nor the mechanics of the notch effect are known. This means that one cannot design a part, calculate the properties really needed, and then procure steel with those properties. While there are a few guides, this highly empirical situation is best met by correlating performance in service, including both good and bad, with the steel characteristics as shown by notched-bar tests. The objective is to determine what steel to accept and what to reject for the service. If steel is not available which has been pedigreed by service, full-scale tests should be performed in the laboratory using steels of different levels of notch toughness to determine which is best suited.

Limiting ourselves to an example where service records and sample material are available, notched-bar tests would be pursued in the laboratory until the necessary level of notch toughness for satisfactory service could be clearly established and defined. This criterion, which might be a go or no-go test, would hold for the one application but might have to be altered for another application, even of the same steel. Another procedure might be the indirect method of selecting a steel which is known to have given good service. Thus it did not take a notched-bar test to steer early ship builders away from bessemer steel. They learned the hard way that if they used openhearth steel they had much less trouble. In about the same way, metallurgists have learned more recently that they should avoid temper-brittle steel or slack-quenched steel for certain applications. It is safe to say, however, that the intelligent use of notched-bar testing is the best approach to the selection and testing of steel for low-temperature service. With this in mind, we may take up a brief consideration of steels in their approximate order of improved notch toughness.

It has perhaps been sufficiently emphasized that ordinary bessemer steel is hardly to be recommended for low temperatures when brittle fracture is to be guarded against. (The recent "killed bessemer steel" appears to come in a different category and should be judged on its merits and service history.) Rimmed steel is likewise frowned upon for the same reason, even when it is made by the openhearth process. It has the same weakness of notch brittleness, but not to the same degree as bessemer steel. Semikilled carbon steels are the cheapest steels which are suitable for outdoor applications. However, this type is quite variable in notch toughness and the statement should perhaps be qualified to say that it is suitable when made right. This is a tonnage steel and has great merit for the milder service conditions, especially for those applications which could not stand the higher cost of steels which are deliberately made with a higher level of notch toughness.

The next is the mild, or medium-carbon, silicon-killed steel, which is tougher at low temperatures and more uniform than the partially deoxidized semikilled type. Still better is the fully aluminum-deoxidized or fine-grained type, especially in the normalized condition. This is necessarily a more expensive steel but is very useful for more severe service. A higher strength steel with about the same level of toughness is the well-known low-alloy or mild-alloy steel. This steel usually has a yield strength of 50,000 psi. but several producers can supply grades having up to 70,000 psi. yield strength. These steels make use of low carbon, fine grain size (actual), thorough killing, and alloy additions to secure their excellent combination of strength and toughness. They are used both as rolled and normalized.

A liquid quench and a tempering treatment give a very effective increase in low-temperature toughness. The broad principle is that tempered martensite gives the best combination of strength, ductility and toughness at low service temperatures. This principle makes it possible to use most of the lessons learned for hardenability, with the major exception that while coarse grain increases hardenability, fine grain increases toughness. Investigations in this field have shown that

the temper-brittle and slack-quenched conditions detract from the toughness and that these effects become more critical at low temperatures.

The effects of the individual alloying elements would require a more complete and careful appraisal than has yet been attempted before valid conclusions could be drawn. The most significant effect is doubtless that on hardenability, although it is rather generally accepted that nickel is beneficial to low-temperature toughness and that molybdenum is effective in suppressing temper brittleness.

Using data given in the Metals Handbook, normalized carbon and alloy steels have reasonably satisfactory energy values in conventional notched-bar tests down to −100° F. or even −150° F., provided the carbon content is not over 0.20%. In the as-rolled condition, such steels are usually more susceptible to low-temperature brittleness. This difference between as-rolled and normalized conditions holds also for the low-alloy steels, but with their low carbon content they are satisfactory in the as-rolled condition down to fairly low atmospheric temperatures.

In the quenched and tempered condition, steels of considerably higher strength can be produced which have good energy values at −100° F., even with 0.40% carbon and above. Presumably 0.30% carbon is better than 0.40%, though the practical question of what carbon and alloy content to use for specific strength levels is not easy to answer on the basis of such data, and this becomes more and more difficult as the required hardness is increased. At −180° F. the necessity for low carbon content and full heat treatment is more pronounced. Fine-grained 4815 steel when quenched and tempered to 228 Brinell has the same V-notch energy value as at room temperature, while other steels are listed which are reasonably satisfactory at this temperature. At −310° F., while it might be advisable to use an insensitive material, there are still a few ferritic steels which exhibit a useful degree of toughness in a standard notched-bar test. The new low-carbon 8½% nickel steel is especially interesting in this connection.

Available evidence is not all in the direction suggested above that structure is the major factor in low-temperature toughness. Jominy★ has published curves which show considerable differences between steels of presumably the same structure of tempered martensite. These steels were 5140, 1340, 4042 and 8640, and they were fully quenched and tempered to Rockwell C-29 to 32. The steel 8640 was the best of the four with respect to both transition temperature and energy values down to −150° F., and steel 4042 was next best in both respects. The steel 1340 had a lower transition temperature than 5140 and might be preferred at low temperatures, but it had lower energy values at room temperature and hence the preference might shift for use at higher temperatures. Jominy points out that the composition of the tempered martensite is also important.

The notched-bar energy values which have been cited here may be said to indicate current trends of thought on the low-temperature toughness of steel. Aside from giving general guidance, such values should not be interpreted too closely because size, stress system and temperature conditions are likewise significant. In this connection, it should be remembered that the meaning is put into such notched-bar tests by correlation with service performance.

Metals Other Than Ferritic Steels

The insensitive nature of most other ductile metals has already been mentioned. If those metals are ductile at room temperature they are ductile at least to liquid air or liquid hydrogen temperatures and the problem of their use at low temperatures should be handled in the conventional way. In spite of the evidence to this effect, a practice has started of requiring nonferrous metals to meet the same specification of 15 ft-lb. at the service temperature that the Boiler Code places on steel. Such a requirement would reject pure lead, since its notched-bar energy values come well under this at all temperatures; this requirement obviously comes from a misconception of notch sensitivity. It should be borne in mind that the figure of 15 ft-lb. has no significance in itself and its use for steel is based on the assumption that it guarantees sufficient ductility under notch conditions for the specific application for which the steel is to be used. Placing such a requirement on a metal like pure aluminum, for example, can only confuse the issue and do an injustice to the metal producer, the fabricator, and the ultimate user of the equipment. Whether or not to use aluminum should be judged on its merits and not on the use of a test that has no known relation to service.

The selection of materials of this class for low-temperature service involves but little that is not required for service at room temperature. The principal materials for use at very low temperatures are the ductile insensitive metals, with the new low-carbon 8½% nickel steel a possible competitor. Alloys which are not structurally stable are known to lose ductility at low temperatures

★"Selecting Automotive Steels", by W. E. Jominy, *Steel*, March 8, 1948, p. 82-86, 122, 124.

and may be unsuited, even if their room-temperature properties are satisfactory. Examples are Hadfield's manganese steel and the precipitation hardening alloys, though these may be good to fairly low temperatures.

Effect of Fabricating Practice

Cold deformation is known to make steel more notch sensitive and can easily be a factor in the performance of parts or structures. Fortunately, the steels that are most likely to be selected for low-temperature service are the ones that are less susceptible to embrittlement by strain aging. When cold working is done in fabrication, it may be necessary to use a more fully killed type of steel, though otherwise a semikilled steel would be suitable. If semikilled steel is used, it should preferably be the kind in which this effect is at a minimum. It also goes, almost without mentioning it, that sharp radii or notches should be avoided, whether put in intentionally in design or by accident. Several failures of welded ships have taught the danger of even minor notches in large rigid structures.

Since welded structures are commonly used for low-temperature service, it is natural that the welded joint should come in for attention, particularly the possibility of doing damage to the material. The steel must not only be all right itself, but it must be able to produce sound welded joints of good quality. Although in some instances the steel has a direct bearing on the soundness of the weld metal proper, the principal point in the selection and use of the steel concerns the properties and characteristics of the heat-affected zone alongside the weld. So important is this that a vast amount of work has been done in studying this point.

With carbon contents above 0.20% and manganese contents of 1.0% or more, particularly if other alloying elements are present, there is a very real danger that cracks will open underneath the weld bead. For all important joints this occurrence should be guarded against by the selection and processing of the steel, by using the proper practice in welding, or by using low-hydrogen electrodes. Sometimes it is advisable to determine the cracking tendency by the underbead cracking test, to set limits on carbon and alloy contents, or to decide what technique should be used in welding. This test brings out the level of "weldability" which is characteristic of the steel.

Considerable attention has also been paid to the question whether the metal of the heat-affected zone is ductile or notch-ductile or, due to its relatively greater hardness, whether it is too brittle for service. More recently attention has also been paid to a softer region of this zone for the same reason. However, as a possible source of trouble in welded structures this factor is of questionable significance and must remain so until it has been demonstrated that failures of structures are due to crack initiation in this zone. There are many welded joints in service which have hard heat-affected zones of reduced ductility and have long since demonstrated reliability. A familiar example is the aircraft engine mount which is made of the air hardening steel 4130 because it *does* harden in the heat-affected zone. On the other hand, it is a good question whether a welding test should be used for steels for low-temperature application, or if tests of the stock are adequate. More information is needed on this point.

Closure

A survey of the mechanical properties of metals at low temperatures, with a discussion of basic principles, has recently been published by Seigle and Brick.* On that account the present discussion deals more with the problem of the selection and use of metals. Good compilations of notched-bar test data are also available† and information of that type has not been included.

The ductile nonferrous metals have been discussed broadly since the requirements for low-temperature service raise no particular metallurgical problem. It was pointed out, however, that there are ferritic steels which are promising competitors for service at liquid air temperatures.

The ferritic steels are the major problem of low-temperature service, and the factors which control their behavior, and hence their selection and treatment, have been discussed in some detail. It has also been emphasized that the engineer has about as much responsibility as the metallurgist to provide a design that is safe and yet places as moderate a requirement on the steel as the conditions warrant. His role becomes more important as the size and rigidity of the structure increase and as the service temperature decreases. The metallurgist should provide the most economical steel for the conditions finally set up.

*"Mechanical Properties of Metals at Low Temperatures; a Survey", by L. Seigle and R. M. Brick, *Transactions*, American Society for Metals, Vol. 40, 1948, p. 813-869.

†"Impact Resistance and Tensile Properties of Metals at Subatmospheric Temperatures", by H. W. Gillett, published by American Society for Testing Materials, 1941; "Behavior of Ferritic Steels at Low Temperatures", by H. W. Gillett and F. T. McGuire, Report of War Metallurgy Committee of the National Research Council, No. W-78, June 1944.

DIFFUSION OF HYDROGEN THROUGH ALUMINUM TUBES

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HYDROGEN is the gas most likely to be present in appreciable quantity in molten aluminum, and considerable information on its effects is available. Much less is known about hydrogen in solid aluminum, largely because of the very low solubility below the freezing point. In general, aluminum can be classed with beryllium, magnesium, zinc, cadmium, thallium, tin, lead, antimony and bismuth as a nonoccluder for hydrogen. The knowledge of the effects of hydrogen on any of these metals in the solid state is limited.

The most significant information concerning hydrogen in solid aluminum has come from investigations of the rate of diffusion of hydrogen through aluminum. Recently a question arose as to the rate of leakage of hydrogen through certain heated aluminum tubes, and measurements were made of this property by the author. Unfortunately the tubes were not of a shape to permit accurate measurements. In spite of this fact and although the object of the investigation was limited, several interesting effects were noted which should add to our general understanding of hydrogen in solid aluminum. In particular, the metallurgical structure of the aluminum may be quite as significant as the oxide film in determining the rate of hydrogen diffusion.

Recently a question arose concerning the leakage of hydrogen through heated aluminum tubes. In measuring the rate of hydrogen diffusion through such tubes, Dr. Russell found that the rate changed rapidly with time at moderate temperatures. The sample recrystallized during the experiment, and this change in metallographic structure may have influenced the rate of diffusion.

Workers with various other metal systems have found that the rate of hydrogen diffusion was markedly influenced by an ionizing discharge. A few experiments in which this effect was investigated are included in this report.

Some Prior Work — Although many workers* have made observations on the rate of diffusion of hydrogen through aluminum, only Smithells and Ransley† have reported extensive quantitative measurements of this effect. These authors observed that the diffusion rate at 580° C. and 290 mm. of mercury pressure increased from 2 to 10×10^{-7} (ml. N.T.P.) (mm. thickness) per (sq.cm. area) (sec.) when the surface was abraded in vacuum, but fell on continued heating in quite pure hydrogen to 1×10^{-7}, after which it was restored to its original high value by re-abrading. The amounts of gas were calculated to the volume at a pressure of 760 mm. of mercury and a temperature of 0° C. (ml. N.T.P.) by the gas laws. The effects of temperature T and pressure P on

*See bibliography in "Hydrogen in Metals", by Donald P. Smith, University of Chicago Press, 1948, p. 283-285.

†C. J. Smithells and C. E. Ransley, *Proceedings* of the Royal Society (London), Vol. A152, 1935, p. 706-713.

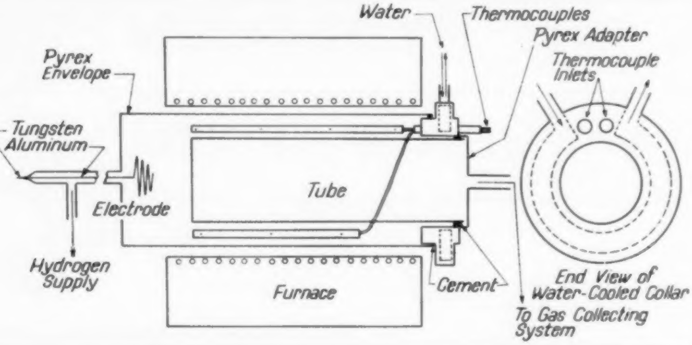


Fig. 1 — Diagrammatic Representation of Diffusion Tube Assembly

the rate of diffusion D were satisfactorily represented by Richardson's equation:

$$D = k\sqrt{P}\, e^{-b/T}$$

where b was 15,600 for a freshly abraded surface and 21,500 for an oxidized surface, while k varied from 3.3 to 0.42 for different states of the surface with P expressed in millimeters. Smithells and Ransley's tube was outgassed at 605° C. before measurement. In the present work the aluminum tubes had not been heated to this temperature.

Experimental* — The tubes (impact extrusions) were 35 mm. in diameter, 20 cm. long, with a wall thickness of 0.5 mm., and analyzed 0.2% iron, 0.1% silicon, 0.01% or less copper, manganese and magnesium. A water-cooled aluminum collar was fitted over the tube at its open end and sealed to it by DeKhotinsky cement. To this collar was cemented a Pyrex envelope 25 cm. long and 6.2 cm. in diameter which enclosed the remaining part of the aluminum tube. This envelope contained an aluminum electrode connected to a sealed-in tungsten wire. The envelope was also connected to the hydrogen supply. The open end of the tube which protruded through the water-cooled collar was cemented to a Pyrex adapter leading to the gas collection system. Six thermocouples insulated by flexible porcelain "fish spines" were sealed through the collar by cement and were wired, three at the top and three at the bottom, at the closed end of the tube and 5 cm. and 10 cm. from the end. The tube and envelope were heated by a nichrome-wound split-section furnace. The diffusion tube assembly is shown in Fig. 1.

The tube collapsed during use when subjected to an atmosphere of hydrogen at temperatures over 350° C. In one set of experiments, tube A was supported by an aluminum bar with external screw threads. In a second set of experiments, tube B was precrimped to give three ridges parallel to its axis and was not supported internally.

This assembly was connected to a vacuum system by which it could be initially evacuated on both sides and then subjected to varying pressures of hydrogen on the outside of the tube while the amount of gas appearing inside the tube was measured. The system employed two mercury diffusion pumps in series backed by a Cenco Hyvac pump. The amount of gas diffusing was measured by the pressure at either of two McLeod gages (ranges 10^{-6} to 10^{-2} and 10^{-4} to 1 mm. respectively)

*Dr. Scott Anderson constructed the original equipment and Kenneth M. Laing and John J. Stokes, Jr., both worked with the author in these experiments. The micrographs and the estimates of oxide coating were made by Fred Keller.

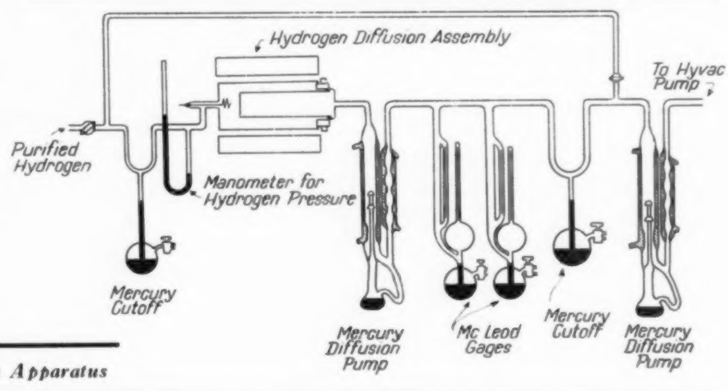


Fig. 2 — Hydrogen Diffusion Apparatus

in a calibrated collector volume between the first diffusion pump and a cutoff to the second pump. Mercury cutoffs were used to minimize contact with stopcock grease. The apparatus is shown in Fig. 2.

The collector volume was determined with the first mercury diffusion pump in operation, by expanding a known volume and pressure of gas from the McLeod gage into the previously evacuated collector volume and then remeasuring pressure. There was, of course, a sharp temperature gradient along the tube, and it was estimated that 120 sq.cm. was at the working temperature while diffusion through the remainder of the tube was negligible.

The hydrogen was the Linde tank product purified and dried by passage through copper turnings at 500° C., freshly heated activated alumina, and a dry ice trap. The helium was the Ohio Chemical Co. tank product, purity 99.8%. This gas was passed through a dry ice trap and was not further purified. The hydrogen in some runs was subjected to a 13,000-volt discharge between the aluminum electrode and the aluminum tube.

Table I — Diffusion of Hydrogen Through Aluminum Tubes

Run	Preheating		Hydrogen Pressure	Temp.	Discharge	Rate of Diffusion*	
						Observed	Net
			Tube A				
1	4 hr.	540° C.	1.6 cm. Hg	475° C.	—	0.20	0.18
2	1	500	1.6	495	—	1.13	1.11
3	1	500	11	505	—	0.94	0.92
4	1	500	33	495	—	1.05	1.03
5	1	500	71	495	—	0.72	0.70
6	16	500	71	490	—	0.12	0.10
7	24	25	2.9	510	—	0.12	0.10
8	—	—	2.9	520	100 watts	0.60	0.58
9	24	500	2.9	490	—	0.08	0.06
10	—	—	2.9	490	100	0.41	0.39
11	—	—	2.9	490	—	0.07	0.05
12	1	500	2.9	490	—	0.07	0.05
13	—	—	70	295	—	0.014	0.000
14	—	—	1.9	305	—	0.014	0.000
15	—	—	1.9	310	100	0.014	0.000
16	2	500	73	500	—	0.077	0.065
17	1	500	32	500	—	0.074	0.062
18	1	500	9	500	—	0.077	0.065
19	1	500	2.1	505	—	0.065	0.053
20	1	500	0.45	495	—	0.030	0.018
21	16	500	0.45	500	—	0.022	0.010
22	1	500	0.45	495	2	0.022	0.010
23	1	500	0.45	495	30	0.060	0.048
24	1	500	0.45	495	70	0.077	0.065
25	1	500	0.45	495	150	0.093	0.081
26	16	500	74 (Air)	500	—	0.011	0.000
27	40	500	71	500	—	0.032	0.020
28	—	—	68	415	—	0.011	0.000
29	—	—	62	300	—	0.008	0.000
30	1	500	72 (He)	505	—	0.035	0.026
			Tube B				
1	8	100	73	100	—	0.013	0.003
2	16	200	75	200	—	0.027†	0.021†
3	50	250	75	250	—	0.053	0.042
4	20	350	75	300	—	0.033	0.027
5	3	300	75	300	—	0.027	0.020
6	6	300	75	300	—	0.030	0.023
7	18	250	75	250	—	0.007	0.000
8	4	300	1.8	300	—	0.015	0.012
9	1	300	1.8	300	80	0.028	0.025
10	2	500	0.9	500	—	0.285	0.276
11	1	500	0.9	500	—	0.193	0.185
12	1	500	3.2	500	—	0.095	0.087
13	3	500	1.6	500	—	0.058	0.052
14	8	500	7.1	500	—	0.025	0.018
15	4	500‡	7.3	500	—	0.023	0.017

*(ml. $\times 10^{-7}$ N.T.P.) (mm. thickness) per (sq.cm. heated area) (sec.).
†Diffusion not constant during run; final rate recorded. ‡Oxygen.

Procedure and Results

The relatively large outgassing of the system necessitated a blank run with no hydrogen outside the tube immediately before or after the measurement of hydrogen diffusion. Even this procedure was inaccurate because the temperature distribution along the tube changed when hydrogen was admitted, and the outgassing rate may have changed correspondingly. Although water vapor was expected, it was observed only at the start of the outgassing, and thereafter the gas was noncondensible, as judged by reading several scales on the McLeod gage.

The tube was sealed in position, evacuated on both sides, brought to temperature, and the outgassing rate measured. Hydrogen at various pressures was then put into the glass envelope, and the rate of gas collection inside the aluminum tube was measured after one minute and then at five-minute intervals for one hour. The net rate was taken as the difference between the rates with and without hydrogen outside the tube.

The significant results are summarized in Table I. The rates are all expressed as:

$$\frac{(\text{ml.} \times 10^{-7}\ \text{N.T.P.})\ (\text{mm. thickness})}{(\text{sq.cm. heated area})\ (\text{sec.})}$$

The first run showed a net rate of 0.18 for 1.6 cm. hydrogen pressure and 475° C. This compares with the highest extrapolated value of about 0.11 obtained by Smithells and Ransley for these

conditions. The high temperature coefficient of diffusion is evident by the fivefold increase at 495° C. The rate decayed rapidly at this temperature in spite of an increase in hydrogen pressure, and after 20 hr. at 495° C. the rate fell to 0.1.

A more than fivefold increase in diffusion rate occurred in the presence of a 100-watt (transformer input) 13,000-volt discharge. The temperature of the aluminum tube may have increased, but there was no change in the thermocouple readings during the discharge.

The diffusion rate for this aluminum tube cooled to 300° C. was too small to measure. Re-investigation of the pressure effect by removing hydrogen from the system at 500° C. after the diffusion rate had decayed showed that the rate decreased as hydrogen pressure diminished. The rates showed a considerable scatter when plotted against the square root of pressure according to Richardson's equation (graph not reproduced here). At approximately 500° C. the diffusion rate increased more than fivefold as the power consumed by the high-voltage transformer producing a discharge was varied from that barely sufficient to maintain a glow (2 watts) up to 150 watts. This result must be presented with the reservation that the true temperature and outgassing rates during the discharge are not known. The diffusion of air through the tube at 500° C. and 73 cm. pressure was immeasurably small. After the tube was exposed to air at 500° C., the diffusion rate for hydrogen was further reduced. There appeared to be an appreciable diffusion of helium through the tube at 505° C. and 72 cm. In fact, the rate of diffusion in this single run was as great as that for hydrogen under the same conditions.

In the second set of experiments, diffusion was measured at lower temperatures in a duplicate tube (B) which had not previously been heated at high temperatures. A measurable diffusion was found even at a temperature as low as 100° C., and the diffusion rate increased regularly through 200 and 250° C. However, the net rate at 250° C. after an intermediate heating of 20 hr. at 350° C. fell from 0.04 to 0.000. Decreasing the hydrogen pressure at 300° C. from 75 cm. to 1.8 cm. decreased the rate by a factor of two. An electrical discharge increased the apparent diffusion rate at 300° C. by a factor of two. The maximum rate observed

Table II — Grain Count Along Tube B After Diffusion Experiment

Section	Grains per Mm.			Grains per Sq.Mm.		Grains per Cu.Mm.
	X	Y	Z	XZ	YZ	XYZ
1*	Unrecrystallized material					
2						
3						
4						
5	18	18	29	522	522	9,396
6	16	16	28	448	448	7,168
7	14	16	39	546	624	8,736
8	17	17	36	612	612	10,404
9	18	16	36	648	576	10,368
10†	17	14	30	510	420	7,140

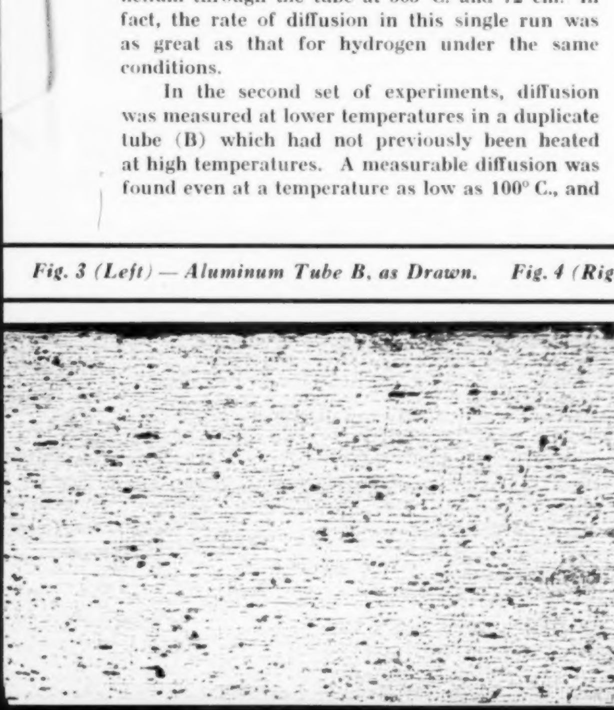
*Unheated open end. †Closed end.
XZ is cross section, YZ longitudinal section, XYZ volume.

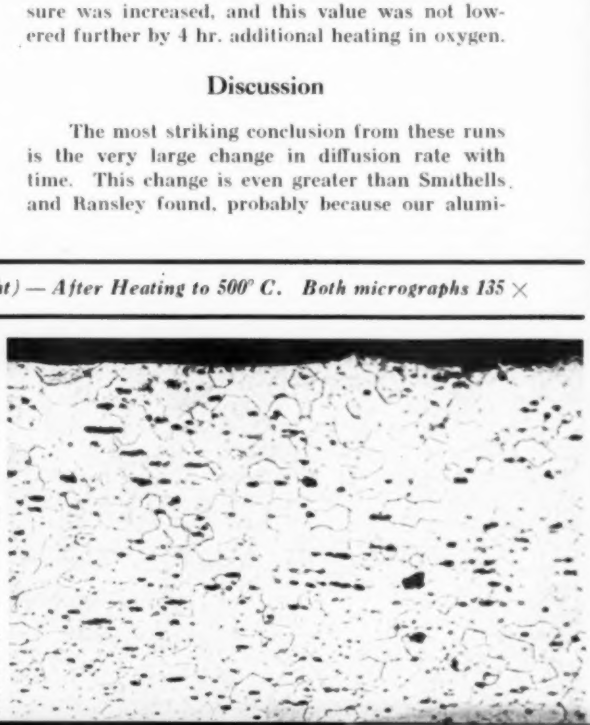
when this tube was heated to 500° C. was only 0.3, compared with 1.1 for the former tube. This discrepancy reflects the large decay which had taken place before the 500° measurement with this second tube. Heating for 15 hr. at 500° C. resulted in a rate of only 0.02×10^{-7} even though the pressure was increased, and this value was not lowered further by 4 hr. additional heating in oxygen.

Discussion

The most striking conclusion from these runs is the very large change in diffusion rate with time. This change is even greater than Smithells and Ransley found, probably because our alumi-

Fig. 3 (Left) — Aluminum Tube B, as Drawn. Fig. 4 (Right) — After Heating to 500° C. Both micrographs 135 ×





num tubes were not heated to high temperature before the diffusion runs. The 500° C. data showed a decrease in diffusion rate by a factor of 50. Even larger differences would result by comparing the measured diffusion rate at 500° C. with that extrapolated from the low temperature runs. The diffusion rate in these measurements did not increase linearly with square root of pressure.

An electrical discharge in the hydrogen increased the diffusion rate more than fivefold. Thus, it appears that hydrogen is carried through the metal in an ionic form and that the rate of ionization of hydrogen on the surface is a major factor in controlling the diffusion rate.

There are two alternate explanations for the very large change in diffusion rate with time. The first is that recrystallization and grain growth of the aluminum is taking place. Recrystallization for this tube is anticipated near 250° C. Figure 3 shows the structure of the as-drawn tube while Fig. 4 shows the structure typical of the tube which was heated to 500° C. The aluminum has, as expected, completely recrystallized and a considerable grain growth has occurred. The grain count after the diffusion experiment along tube B measured at ten equally spaced points from the unheated open end to the closed end is shown in Table II.

The second probable cause of a large change in diffusion is that the oxide on the aluminum is increasing in spite of the precautions to purify the hydrogen. This oxidation might be expected to be particularly pronounced at temperatures over 350° C. However, the oxide film after the runs indicated no appreciable increase in total thickness during the measurements. These tubes seemed to have a relatively thick aluminum oxide coating in the as-drawn condition. The estimates of total aluminum oxide thickness do not preclude the possibility of an increased oxide thickness at grain boundaries or other regions through which the diffusion might be occurring most rapidly.

Summary

1. The rate of hydrogen diffusion through a particular type of aluminum tube has been measured at temperatures from 100 to 500° C. and pressures from 1 to 75 cm. of mercury.

2. The rate was found to change rapidly with time at moderate temperatures. The diffusion at 250° C. in 1 atm. of hydrogen diminished from 0.04 (ml. $\times 10^{-7}$ N.T.P) (mm. thickness) per (sq.cm. heated area) (sec.) to 0.000 after 20 hr. heating at 350° C. Similarly, extremes of 1.1 and 0.02 were observed for the diffusion rate at 500° C.

3. Because of the high rate of decay, no meaningful data on the effect of temperature and pressure on the rate of diffusion of hydrogen through aluminum in its highly diffusing state were obtained.

4. The sample recrystallized and considerable grain growth occurred during these measurements. No large increase in total oxide film thickness was observed, although this does not eliminate oxidation as a major factor influencing diffusion rate.

5. The rate was increased more than fivefold when a high-voltage discharge was passed through the hydrogen.

6. The diffusion of oxygen at 1 atm. at 500° C. was immeasurably low. A diffusion of helium was indicated in a single run at 500° C. and 1 atm. pressure.

National Officers Nominated

IN CONFORMITY with Article IX of the Constitution of the American Society for Metals, the duly accredited nominating committee met in Detroit on May 20 and made the following nominations for national officers of the Society:

ARTHUR E. FOCKE, for President for one year.
WALTER E. JOMINY, for Vice-President, one year.
RALPH L. WILSON, for Treasurer for two years.
ELMER GAMMETER, for Trustee for two years.
THOMAS G. DIGGES, for Trustee for two years.

All of the men nominated have been notified by telephone and have accepted the nomination.

Article IX on the nomination, election and term of officers also contains the following:

Section 1 *(c)* **Additional Nominations.** After publication of the names of the candidates nominated by the Nominating Committee and by the Committee for Nomination of a Secretary for the Society, if any, and at any time prior to July 15th of the same year, additional nominations for any or all of the vacancies may be made by written communications addressed to the Secretary of the Society and signed by any fifty (50) members and/or representatives of member firms or corporations.

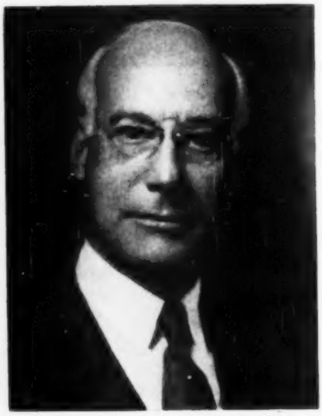
(d) **Voting at Annual Meetings.** If no such additional nominations are received prior to July 15th, nominations shall be closed and the Secretary, at the next succeeding annual meeting of the members, shall cast the unanimous vote of all members for the election of the candidates so nominated.

A. L. BOEGEHOLD, *Chairman*

N. B. BROWN — L. K. JETTER
A. W. DEMMLER — L. W. OSWALD
W. J. HARRIS — W. A. PENNINGTON
O. J. HORGER — DANA W. SMITH

Members, Nominating Committee.

DISTINGUISHED METALLURGISTS IN ALLOY STEELS



Bradley Stoughton

Consulting Engineer
Bethlehem, Pa.

Citation: "Educator of two generations of makers and users of fine alloy steels"

FIRST as HENRY MARION HOWE'S private assistant (1897) and later as his associate in the metallurgical department of Columbia University — then at the peak of its importance and influence by virtue of a brilliant faculty — BRADLEY STOUGHTON started his lifelong career as educator with incomparable advantages, and rose to high estate as student, writer and teacher. So it was that in 1923 (after an interim of eleven years as secretary of the American Institute of Mining Engineers) he was the logical successor of JOSEPH W. RICHARDS, that second titan of American metallurgy, as head of the department of metallurgy at Lehigh University.

He was not only a good teacher; he was a good friend to the young men in his classes. He would give any amount of time to a student who wanted help in deciding a personal problem, either a small one or a major decision on what direction his career should take. Such a man as STOUGHTON in a college cannot avoid enlarged responsibilities, and so it was that in 1937 STOUGHTON became Dean of Engineering, a position he held until his official retirement three years later. But he was too energetic really to retire — even then he continued teaching his favorite courses on iron and steel as Professor Emeritus.

Thus for two generations he has helped young men to be skilled in the arts and sciences of manufacture, fabrication and heat treatment of alloy steel. An executive of Bethlehem Steel Co., long an observer of this important activity, appraises BRADLEY STOUGHTON in these words:

"His intimate knowledge of the theoretical and practical problems of the manufacture of steel, combined with a charming personality, have made him an outstanding figure, not only with his students but also with the men of our industry."

Hyman Bornstein

A DEGREE in chemical engineering from Armour Tech and graduation from John Marshall Law School provided the educational background of HYMAN BORNSTEIN, Director of Laboratories for Deere & Co. since 1920. For more than a quarter century, HY BORNSTEIN has guided the selection of materials and processes for John Deere farm machinery. This has been the period of development of power farming, with steady improvements in implements.

Hyman Bornstein

Director of Laboratories
Deere & Co., Moline, Ill.

Citation: "Pioneering metallurgist in the farm implement industry, responsible for many applications of special steels"

In the early days of farm tractors, some 25 years ago, the gearing was crude and there was little need for accuracy of shape or dimension. Consequently, carbon steel gears, water quenched, were adequate. With the need for better gearing came an appreciation of the necessity for control of dimensions. This meant the use of oil quenching and the adoption of alloy steels. Similar applications were made on axles and other structural parts.

HY BORNSTEIN has been a strong champion of alloy steel where it is justified, and just as strong a defender of carbon steel where alloying elements are unnecessary. The net result has been an increasingly large amount of alloy steel fabricated by Deere & Co. and distributed to farms throughout the world.

A Captain of Ordnance in the first World War, BORNSTEIN has twice made the transition from swords to plowshares. He was on the Iron and Steel Committee of the War Engineering Board and chairman of one of the Army Ordnance Industrial Integration Committees during the second war.

HY BORNSTEIN'S chief hobby has been the selection and training of young metallurgists. His numerous "alumni" scattered throughout industry extend his teachings on the sound application of alloy steels.

Karl D. Williams

Head of Standards Branch
Bureau of Ships, Navy Dept.
Washington

Citation "for his efforts toward steady improvement of naval propulsion systems by the use of alloy steels"

A Buckeye, and graduate of Kenyon College in sylvan Gambier, Karl Williams worked for five years under the tutelage of John Cox in Midvale's forging department before entering government service as inspector for the Navy's bureau of steam engineering (1910). Within five years he was civilian head of the specification and inspection division, and thus for nearly 40 years has wielded great influence on the uses of metals and alloys in the construction of American naval vessels.

In these years there has been a constant increase in cruising speed—the ship that can steam faster than its adversary can overhaul it, stay safely beyond range of its heavy guns, and keep battering away. More and more power must therefore be generated and transmitted to propellers, and so Karl Williams devoted his knowledge and experience to the mutual problems of steelmakers and naval engineers and devised standards and specifications covering alloy steel gearing, shafting and forgings that could be manufactured commercially and would be adequate.

This influence extended on undiminished during World War II, as is thus set forth by the Secretary of the Navy when making the Distinguished Civilian Service Award:

"By reason of his keen foresight, scientific knowledge and rare good judgment, Mr. Williams has rendered distinguished service to the Navy in establishing and carrying out programs to determine readjusted but acceptable criteria for acceptance of both ferrous and nonferrous materials and equipment. At the beginning of the war he set in motion a broad research program for the study of steel quality, resulting in the acceptance of critically needed material which would have unnecessarily been rejected under previously existing criteria.

"For the great initiative and ability which he demonstrated in fulfilling several programs of highest importance, Mr. Williams has distinguished himself in a manner richly deserving of the Navy's highest civilian award."

Oscar L. Starr

Vice-President
Caterpillar Tractor Co.
San Leandro, Calif.

Citation "for early recognition of those properties of alloy steels that are indispensable to diesel engines"

Born in San Francisco in 1885, Oscar Starr is a Californian to the core.

He learned the machinist trade as a youth, meanwhile studying engineering and manufacturing so successfully that by 21 he was a superintendent for the Gorham Engineering Co., manufacturing marine gasoline engines. Since 1912 he has been with C. L. Best Tractor Co. and Holt Mfg. Co., predecessors of Caterpillar Tractor Co.; with the latter he has been in charge of manufacturing and of research. Complete redesign of tractors in 1918 substituted heat treated alloy steel parts for many parts of carbon steel, introduced antifriction bearings, reduced weight 40%, and delivered more horsepower. At a considerably later date, when diesel engines were being developed, some entirely new problems were met. These are described thus by one of Caterpillar's executives:

"Mr. Starr was sure that the smooth functioning of these engines was dependent upon the alloy steels from which the metering valves and pumps are made. The diesel engine itself awaited full exploitation until metallurgy had supplied the essential materials and appropriate heat treatments. Mass production of these small parts, made to highly precise measurements, also had to maintain stable operating characteristics with clearances controlled to within a few millionths of an inch. In the course of the experimental developments, Mr. Starr visited the Bosch factories in Europe which produced diesel fuel injection and metering valves, and was told by the foreign engineers and factory managers that such precise equipment could not be made by mass production techniques but must always be hand fitted. As a matter of fact, however, in 1931, the Caterpillar Tractor Co.'s factory at San Leandro, Calif., under Mr. Starr's direction, had set up and was producing under progressive mass production methods these very items!

"The uniform quality, high hardness and the mechanical stability of alloy steels were responsible for the interchangeability of these pump plungers and barrels to mechanical tolerances less than 25 millionths of an inch. Since diamond lapping and uniform stock removal in the last stages of manufacture of these parts would not tolerate variations in hardness or change of dimension, you can see why Mr. Starr placed so much emphasis on that factor."

IMPROVED STEEL-MAKING TECHNIQUES

Reported by
Ralph W. Farley
Special Mill Metallurgist
Chicago District, Republic Steel Corp.

THE 32nd annual meeting of the National Openhearth Steel Committee (jointly with the Blast Furnace, Coke Oven, and Raw Materials Committee) of the American Institute of Mining and Metallurgical Engineers was held in Chicago late in April.

The first day was devoted to a visit to the Gary Works of Carnegie-Illinois Steel Corp.

The second day opened the technical sessions of both branches of the conference, beginning with the general session on the openhearth, presided over by E. G. Hill, vice-chairman of the Openhearth Committee. This day was highlighted by presentation of the McKune Award paper, entitled "Liquid Iron and Steel Temperatures in Practice", by Theodore B. Winkler of Bethlehem Steel Co.; and in the evening by the Annual Fellowship Dinner, with H. J. Watt of Carnegie-Illinois as toastmaster and Clarence B. Randall of Inland Steel Co. as principal speaker. Entertainment was by the "Singing Men of Steel", of Carnegie-Illinois South Works, Chicago; this feature was a surprise to many operators, who never knew there was so much harmony in a steel mill.

Technical meetings of the day included, for the openhearth men:

1. Problems of sulphur elimination in steel.
2. A second session on basic practice, covering production problems and the use of oxygen.
3. Acid openhearth operations.
4. Cold metal operations and foundry practice.

For the Blast Furnace and Coke Oven conferees was this fare:

1. A general session on coke, coking, and ammonium sulphate recovery.
2. Operating differences between large and small blast furnaces.
3. Rehabilitation of coke ovens.

It was a busy day; it had only one morning and one afternoon, but it had seven meetings.

The third day brought these meetings on openhearth subjects:

1. Refractories and masonry.
2. Metallurgy of the openhearth process.
3. Quality session.

And for the blast furnace, coke oven, and raw materials people, their annual luncheon and business meeting (with Chairman T. L. Joseph presiding) and meetings for the discussion of

1. Agglomerating (having to do with nodules, sinters, and briquettes).
2. Ore blending.

In brief, this was the conference; now for the details, starting with the World's Largest Steel Mill.

Some Features of the Gary Plant

On the 18th of April in '75 Paul Revere took a long ride; on the 18th of April in '49 visitors to the Gary Works took a longer ride. Revere was handy, we understand, with silver, bell metal, and such; but he didn't have openhearth steel, so he had to ride his horse. The visitors at Gary, mainly because of the openhearth steel and the courtesy of Carnegie-Illinois, rode in buses.

The day will long be remembered for the immensity of the plant and its operations, the

orderliness of a well planned layout which would not let its phenomenal growth interfere with its muscle-flexing, and for the cordial welcome and frank display of facilities and processes.

The bus tour proceeded through the coke and chemicals division, past the slip and ship-turning basin, a few of the 12 blast furnaces, the bessemer converters, and the five openhearth shops, past the laboratories and the vast maintenance shops, and on to inspection of No. 5 openhearth shop, the rail mill, the steel wheel plant, and two of 13 merchant mills; and so to lunch in the Gary Works luncheon club with Ray Dwyer, Gary's openhearth superintendent, doubling as head waiter.

The world's largest of anything can usually present many arresting statistics; in a steel mill such statistics stretch the imagination. In a plant occupying 2200 acres along the southern tip of Lake Michigan, 20,000 people produce annually nearly six million tons of ingots. 600,000 tons of coal and 4,500,000 tons of ore are stored, to feed 1055 coke ovens and 12 blast furnaces. The furnaces are of various ages and cast 800 to 1500 tons of iron daily; one is being rebuilt into a 28-ft. hearth with capacity of 1700 tons.

The steelmaking units comprise three bessemer converters and 53 openhearth furnaces. The converters work in duplex practice with three tilting openhearths. No. 5 openhearth (the alloy shop) has eight 185-ton furnaces. This shop, on scrap practice, operates with a 45% hot metal charge; with 65% hot metal on flush practice.

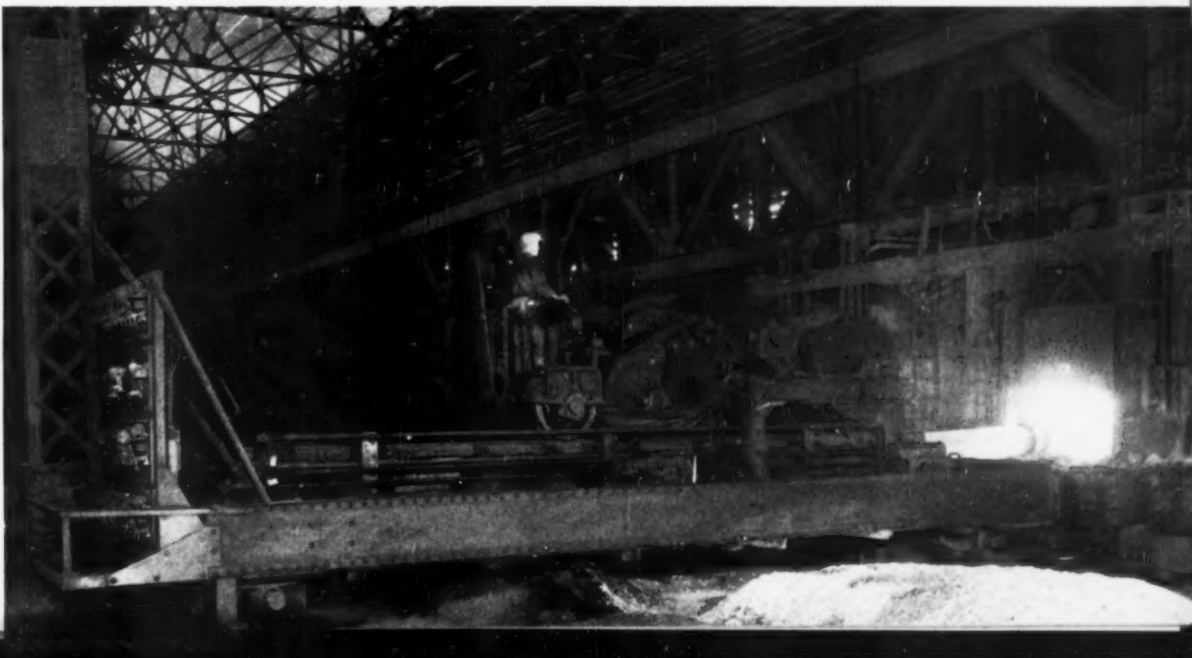
The rail mill rolls many sizes and shapes of rails from 24x24x89-in. ingots in some nine breakdown and eight shaping passes. Two or three hot saws simultaneously cut the product of each ingot into standard lengths.

The wheel plant makes about 1000 steel wheels (0.54 to 0.67% carbon) per day, a monthly tonnage of about 120,000. Square blooms are forged to rounds, cut to length, and reheated. The slugs are blanked on a 10,000-ton press, the centers punched out on a 1000-ton press; the blanks then weigh 1400 to 1500 lb. Reheated, the web and rim are formed, and a wheel number pressed on. Wheels are finished on rolls, heat treated to customer's specifications, and machined. All wheels are matched up in pairs.

The 13 merchant mills roll 145,000 tons per month and are capable of making some 40,000 different sections. They discharge into a common warehouse over a half-mile long, served by more than 30 overhead cranes and accommodating 120 railroad cars on 24 tracks. (On the subject of tracks, there are 250 miles of it in the entire plant, with about 3000 car movements per day.) But coming back to the mills, the conferees inspected the 38-in. strip mill which produces coils up to 21⅞ in. wide, and the precision bar mill which produces bars to a tolerance of ±0.003 in. This mill was rolling $\frac{13}{16}$-in. rounds that day; the bars were coming off at about 30 miles per hr.

While we are on the statistics, consider this one: An accident severe enough to cause loss of time occurs but once in 175 man-years of work. But in the eyes of Gary's officials, of the corporation

Charging Machine in One of the Openhearth Shops at Gary Works, Carnegie-Illinois Steel Corp.



of which it is a member, and of the American steel industry, this is too frequent! Later in the conference D. A. Farrell, supervisor of safety of Carnegie-Illinois Steel Corp., delivered a paper entitled "Single Objective Safety", outlining a statistical method of studying hazards and the frequency and mode of occurrence of accidents. By such investigational methods, by education, by example, by constant vigilance, the steel industry moves forward in the reduction of frequency and severity of accidents, making the steel mill an ever safer place for men to work.

Temperatures of Steel During Refining

The McKune Award paper by T. B. Winkler of Bethlehem Steel Co. described a survey of temperatures by means of the platinum thermocouple, beginning with the blast furnace cast and ending with steel held in the ladle. This paper will now be reviewed at some length, because of the importance and timeliness of the information it contains.

Temperature variations were explored during the blast furnace cast, the transfer to hot metal mixer, and to the openhearth hot metal ladle; measured also were the temperature changes of the openhearth bath associated with normal oreing, with oxygen practice, and with other furnace additions; the drop in steel temperature during tapping and while it was held in the ladle. Accurate information of this sort is rare indeed, yet by its use temperature ranges have been established to minimize not only skulling in the ladles but stickers in the ingot molds.

Dr. Winkler considers the platinum thermocouple capable of an accuracy of ±10° F. under repeated use in routine operation. He cautions that it is not a fool-proof instrument; however, the care and judgment required are not prohibitive. His reported depths of immersion are 18 to 24 in. in hot metal, and 18 in. in steel.

Table I of the author's paper is reproduced:

Temperature Variation of Hot Metal

Maximum temperatures, cast to cast ..	2600 to 2765° F.
Maximum variation within a cast ..	75° F.
Drop from skimmer to full "submarine" transfer ladle	100° F.
Drop in submarine ladle (covered) during approximately 1½-hr. transfer to openhearth mixer	40° F.
Drop in open-top transfer ladle during approximately 1½-hr. transfer to openhearth mixer	80° F.
Drop from submarine ladle, through mixer, to openhearth hot metal ladle	140° F.
Maximum temperatures in openhearth hot metal ladles	2375 to 2425° F.

The results of his study of heating rates in 200-ton heats are very interesting:

In oreing practice, in the range of 0.35 to 0.50% C, at temperatures up to 2900° F. and with no additions going in, it requires about 200 gal. of oil per hr. to hold the bath at even temperature. For heats being decarburized with oxygen this oil consumption raises the temperature of the bath 1.5° F. per min.

For baths under 2900° F., where 350 gal. of oil per hr. produces a rise of 2.7° F. per min.; the same fuel rate will heat baths only 1.6° F. per min. if their temperature is over 2900° F.

Additions of ore, lime or ferro-alloys lower the bath temperature, but other materials which produce heat will minimize or overcome such a chill. For instance, 1500 lb. of spiegel in a 135-ton bath produces no change in temperature. The amount of cooling by various amounts of the endothermic alloys has been worked out, ranging from 10° F. for 2000 lb. added to 135-ton baths, to about 75° F. for an 8000-lb. addition.

Temperature variations *within* the bath are found to be insignificant in an active bath, but very considerable if it is quiet. This confirms results of other investigators, and is an important point to keep in mind in any method of pyrometry.

Temperature drop from furnace to ladle is dependent upon the ladle lining, its temperature, the length of the tap, and the amount and kind of additions. Low-carbon rimming steel averages a 70° F. drop, which is about 7° F. per min., and the cooling rate seems to be independent of heat size. But this is for very small ladle additions; the temperature drop decreases with increasing aluminum additions, and with 3¼ lb. per ton going in the ladle on fully killed low-carbon grades, there is no drop at all! For ladles just relined, the temperature drop increases about 20° F. Ladle cooling is somewhat greater for electric heats than for openhearth, probably due to lighter slags. But in any case the rate of drop is found to be only about 3° F. at end of tap, and has fallen to about 1° per min. after a half hour; this makes it appear rather hopeless to expect worthwhile cooling of a bath somewhat too hot to pour by holding it a long time in the ladle.

(Add two new descriptions of openhearth installation of the immersion pyrometer. Both employ the radiation principle. As reported in the last two conferences, these instruments are catching on with the furnace operators, quickly proving their potentiality for greater accuracy than either the optical pyrometer or the melter's "calibrated eye", as we move toward that standardization of bath temperature measurements envisioned by Dr. Sosman in the Howe memorial lecture of 1948.)

New Ideas on Sulphur Control

In a discussion of the desulphurization problem, it was remarked that any reasonable amount of sulphur can be eliminated if one wants to take the penalty in lime and time, either at the blast furnace or at the openhearth. But what of the possibility of chemical treatments of the iron at some point *between* these operations? The fused sodium hydroxide treatment used by the A. M. Byers Co. was reported to this meeting by E. P. Best, plant metallurgist of Byers' Ambridge plant. This appears to work with something over 90% effectiveness. The conditions for best results are maximum contact between slag and metal, absence of contaminating materials, and temperature between 2450 and 2600° F. The treatment also takes out 0.10 to 0.20% of silicon, and drops the temperature nearly 200° F.

There are other chemical means for desulphurization. A preliminary report on another well planned attack on the problem was read by H. M. Griffith, works manager of Steel Co. of Canada, Hamilton, Ont. Experimentation is under way at other points, with a number of reagents. Final reports will be awaited with interest.

Another method was mentioned in a discussion of various factors affecting sulphur in the openhearth bath: Precipitation of high sulphur contents with manganese is effective if the manganese content is over 2.8%; it is also more effective if the steel is held longer in the hot metal ladle. But this much manganese will apparently be hard to get in the foreseeable future, even if the maximum of slag is recycled.

The same speaker has investigated sulphur pickup from the flame. In his shop, coke oven gas will strongly sulphurize the charge, fuel oil to a lesser degree, and natural gas not at all. Relatively speaking, this is the lineup which must hold true generally, but the sulphur content of fuel varies in different localities. Further, sulphurization depends upon equilibrium conditions, therefore upon the sulphur content of the charge as well as upon that of the flame. These factors must be considered for the individual case; any decision to increase desulphurization in the blast furnace, or to apply any desulphurization treatment to the hot metal, must be based upon a study of the equilibrium between flame and charge under your own conditions. Too often the point is argued on the basis of results obtained in some other shop, considering only the sulphur content of the flame, and neglecting that of the charge.

The benefit to be derived from the flush-off also is in dispute. This may be another problem for solution under particular conditions of an individual shop and practice. A real eye-opener came in one report on the sulphur content of the rust layer on scrap:

Type of Scrap	% S in Base Metal	% S in Rust
Mixed	0.029 to 0.035	0.14 to 0.35
Sheet	0.007 to 0.018	0.31 to 0.38
Strip	0.010 to 0.024	0.23 to 0.49
Bloom butts	0.017 to 0.027	0.32 to 0.37

Factors Affecting Steelmaking Rates

Reports on the desirability of using oxygen in the openhearth continue at some variance, but the pattern is taking shape. In the basic ingot shops, except for the very low-carbon grades, the economies realized have not measured up to the hopes. In part, at least, this is due to the high cost of high-purity oxygen and the expense of a shortened roof life. Two plants for the production of 93 to 95% oxygen are under construction in the Pittsburgh area. If they can make cheaper oxygen it may improve the outlook considerably. Compressed air has been found ineffective, and produces too much splash.

Some melters of basic foundry steel appear more enthusiastic, in spite of shorter roof life, reporting a saving of 13% in heat time, increased tonnage from 15 to 17.1 per hr., and saving 500,000 B.t.u. per ton. They find that the increase in temperature hastens solution of lime, and the sulphur finishes lower. In the foundry, compressed air still seems to be worthy of consideration.

Someone spoke of the oxygen jet, which is a water-cooled pipe, not immersed in the bath and therefore not consumed, stating that it worked as effectively as the lance, without troubles from splash. This should be better for the roof. But when compressed air was tried, the increased gas volume brought back the splash. We wonder whether the jet has been overlooked. Has it had a fair trial?

The evaluation of various other factors influencing openhearth furnace production was reported by Messrs. S. F. Elam and A. P. Woods of the Ashland and Middletown plants of Armco Steel Corp., respectively. These reports come out of their exhaustive statistical studies — the kind of work which won a McKune Award a few years ago. It was quite interesting to note the number of factors which have opposite effects in these two shops, working under different conditions. For example, the per cent iron in the charge decreases production (due to blowing) in one shop which uses sinter and gas, and increases it in the other shop using a denser oxide and fuel oil. Some

(Continued on p. 878)

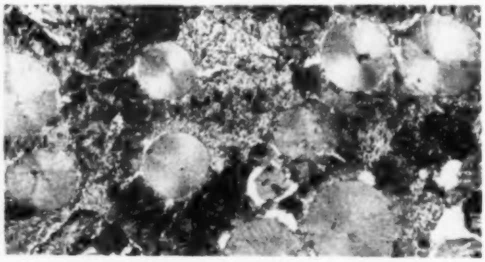
CORRESPONDENCE

Belgian Research on Nodular Cast Iron

GHENT, BELGIUM

To the Readers of METAL PROGRESS:

Since the end of 1947, the question of nodular graphite as a structural element in cast iron has been studied in the metallurgical laboratory at the University of Ghent. Our work has two purposes: *(a)* A study of the systematic production of nodular cast irons and their malleablizing, and *(b)* a theoretical inquiry into the formation of nodules.



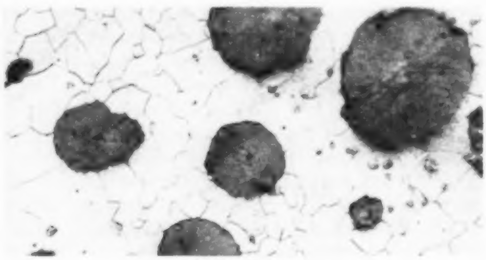
As Cast, 200 ×

At present we can regularly produce nodular graphite, even in cast irons having 0.1 to 0.13% sulphur before treatment and throughout sections 100 mm. in diameter. We have determined that the method of adding the magnesium alloy (for example, the commonly used 50-50 nickel-magnesium) is of utmost importance; the two methods currently used assure an excellent flushing of the liquid metal with magnesium vapors and yield regular results for cast irons running at least 2.25% silicon. A high carbon content, guaranteeing a hypereutectic composition, is advantageous but results have been obtained with carbon contents of 2.7% and silicon 2.5% — that is, with definitely hypo-eutectic compositions.

We have obtained a tensile strength as high as 85 kg. per sq.mm. (120,000 psi.) with an elongation of 2.25% (test bar gage length four times the diameter), on samples taken from the center of cast cylinders 100 mm. in diameter. In general, however, the results average about 70 kg. per sq.mm. (100,000 psi.) and correspond quite well with those reported by C. K. Donoho (*American Foundryman,* February 1949) and the International Nickel Company (*Iron Age,* Feb. 17, 1949).

In the as-cast state and for certain applications, nodular cast irons seem destined to replace [other] cast irons and even cast steels.

Another field — perhaps less extensive, but no less interesting — is that of nodular malleable iron. We know that a short anneal, for example, 1 hr. at 1550° F., followed by slow cooling from the transformation temperature, renders nodular cast iron as ductile as black heart malleable iron. The micrograph reproduced below represents the structure of a malleable iron having the following properties: 50.7 kg. per sq.mm. (72,000 psi.) tensile strength, 41.5 kg. per sq.mm. (59,000 psi.) yield strength at 0.2% strain, 22% elongation (gage length equal to four times the diameter), 24.8% contraction in area, and 160 Brinell.



Annealed, 250 ×

Aside from the higher hardness and consequently lower workability (and lower weldability compared with European malleable iron) nodular malleable compares favorably and lends itself to the fabrication of parts having thick sections.

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NEW STRUCTURAL DIAGRAMS FOR ALLOY CAST IRONS

By H. Laplanche
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In a previous article (*Metal Progress* for December 1947, p. 991-993 and data sheet) I have given a new structural diagram, relating the silicon and carbon contents of cast irons to the resulting microstructure, for a given average cooling rate obtained when a test cylinder 30 mm. in diameter is cast in ordinary foundry sand. The curves of this diagram were established on the basis of the relation between the percentages of silicon and carbon, and the tendency of the carbide to be dissociated into graphite and ferrite *during solidification*. This tendency may be expressed by the factor

$$K = \frac{4 \times Si}{3}\left(1 - \frac{5}{3C + Si}\right)$$

in which C and Si are the carbon and silicon contents, as given by the ordinary chemical analysis.

In a general way, the value of this factor K is proportional to the ratio of the graphitic carbon to the total carbon after cooling, for irons that are neither completely white nor wholly ferritic. Therefore, if λ be a coefficient varying with the mean speed of cooling, the expression

$$\frac{C_{graphitic}}{C_{total}} = \lambda K$$

applies to all cast irons that contain at the same time graphite and pearlite (mottled, pearlitic and pearlitic-ferritic cast irons).

As examples, there will be found in Table I some numerical results obtained on samples of cast irons of various compositions, prepared synthetically with very low contents of manganese, phosphorus and sulphur. It will be seen that for the irons 2, 3, 4 and 5, containing both pearlite and graphite, the coefficient λ is almost constant.

I have shown that the analogy between the curves K and the experimental curves of Uhlitzsch and Weichelt (Dissertation, Sächs Bergakademie Freiberg, 1933) is striking. In the two diagrams, the curves are divergent toward increasing total carbon, and convergent toward increasing silicon contents.

It should be noted that the curves for $K = 1$, $K = 2$, $K = 3$, and so on, are fixed for ordinary cast irons. What varies, when the cooling rate of the alloy is changed, is the position of the limiting curves of the various zones, in relation to these fixed curves. For instance, if the diameter of the test plugs be reduced, it is obvious that all the limiting curves of the zones are shifted toward the right. With a sufficiently high cooling rate, a cast iron with the index 1.2 (which shows a wholly

Table I — Numerical Results on a Series of Pure Cast Irons

No.	Composition			$\frac{C_{graph.}}{C_{total}} = \alpha$	Coefficient K	Coefficient $\lambda = \frac{\alpha}{K}$
	C_{total}	Si	$C_{graph.}$			
1	2.25	1.80	0	0	0.99	0
2	2.80	1.92	1.60	0.575	1.32	0.43
3	3.35	2.30	2.88	0.860	1.82	0.47
4	3.64	2.50	3.45	0.956	2.09	0.45
5	3.80	2.61	3.70	0.973	2.23	0.44
6	4.10	2.90	4.10	1.000	2.59	0.38

pearlitic matrix in the above-mentioned test piece) can give a mottled structure, and even a wholly white structure (free cementite network in a pearlitic matrix).

With separately cast test bars 30 mm. in diameter, poured in green sand, the limits of the various structural zones are established as follows (Fig. 1):

Limit between white irons (zone I) and mottled irons	$K = 0.65$
Limit between mottled irons (zone IIa) and wholly pearlitic irons	$K = 0.85$
Limit between wholly pearlitic (zone II) and pearlitic-ferritic irons	$K = 2.05$
Limit between pearlitic-ferritic (zone IIb) and wholly ferritic irons (zone III)	$K = 3.10$

But with a test plug 20 mm. in diameter, the limits of the above zones become approximately:

0.75 1.10 2.25 3.40

and with a plug 10 mm. in diameter, they become:

1.05 1.50 2.35 3.50

Among the five structural zones, the field of wholly pearlitic matrix (zone II) is practically the most interesting, because it corresponds to "high-resistance" irons having the best mechanical characteristics. In order to simplify the following data, I shall consider only the curves limiting this pearlitic zone. The graph in the upper left corner of p. 840-B shows these limiting curves for cylindrical test bars 30, 20 and 10 mm. in diameter.

Regarding the alloy cast irons, it is obvious that the fields of white and mottled irons (I and IIa) are increased by all the elements stabilizing the carbides (chromium, tungsten, molybdenum, sulphur, and so on). All the limiting curves of structural zones are shifted toward the right, other factors being equal. These elements, therefore, act in the same way as an increase in the mean speed of cooling during solidification.

On the contrary, the nickel and other graphitizing elements act in the same way as a decrease in cooling speed; all the structural zones are then shifted toward the left.

The five diagrams for alloy irons on p. 840-B show the limiting curves of the pearlitic field for cylindrical test bars 30, 20 and 10 mm. in diameter with nickel contents of 0.5, 1 and 1.5%, and with chromium contents of 1 and 2%. Similar curves for 1 and 2% molybdenum are shown on p. 841.

Designating by $+\Delta Si$ the value of the shifting produced by an addition of 0.5% chromium or molybdenum toward the right, and by $-\Delta Si$ the shifting produced by 0.5% nickel toward the left, the numerical values of $\pm\Delta Si$ are plotted in the last diagram, on p. 841, against the total carbon content, for different diameters of the cylindrical test bars.

It should be noted that the value of the shifting for a given percentage of the alloying element and a given rate of cooling is not constant. It increases when the total carbon content decreases. Therefore, the equation of the curves is not the same as for common cast irons.

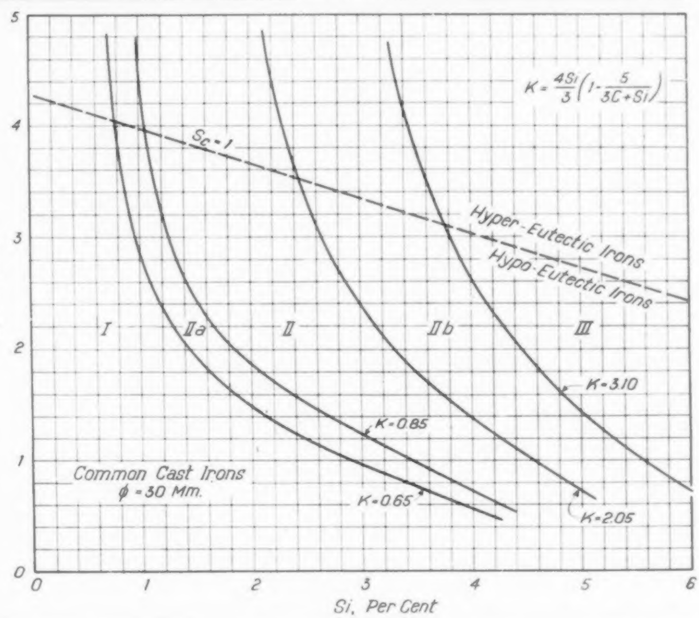
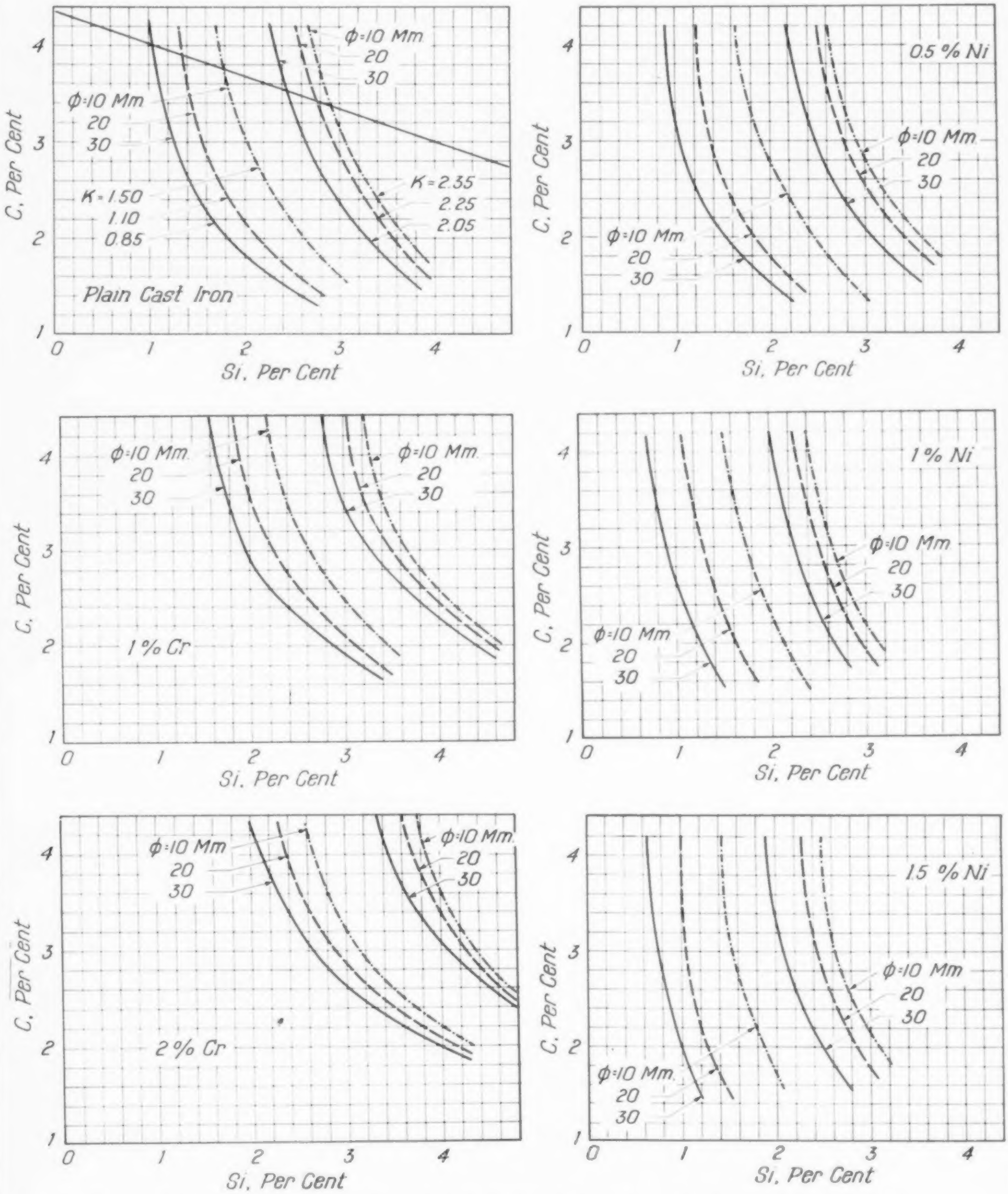


Fig. 1 — Curves Limiting the Structural Zones in Common Cast Irons, for Cylindrical Test Bars 30 Mm. in Diameter. I, white irons; IIa, mottled irons; II, irons with a wholly pearlitic matrix; IIb, irons with a pearlitic-ferritic matrix; III, irons with a wholly ferritic matrix.

Structural Diagrams for Alloy Cast Irons

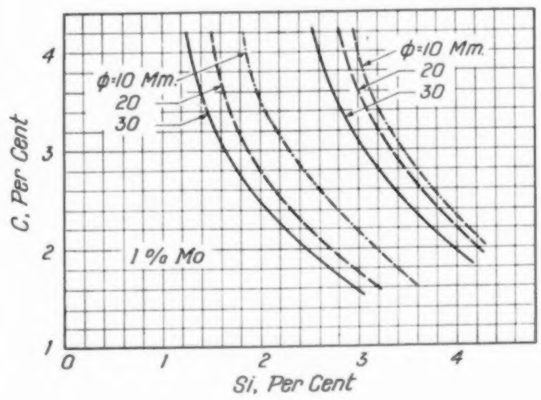
Sheet I of Two Prepared by H. Laplanche, Citroen Works, Clichy, France

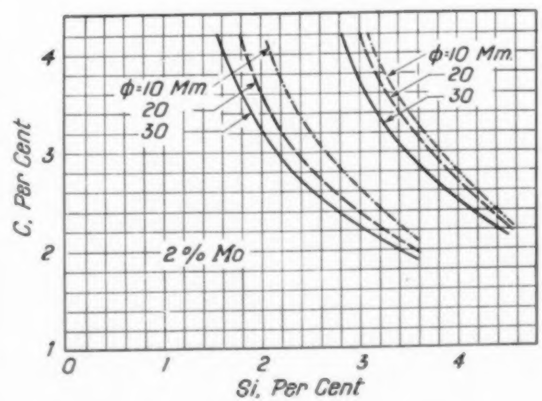


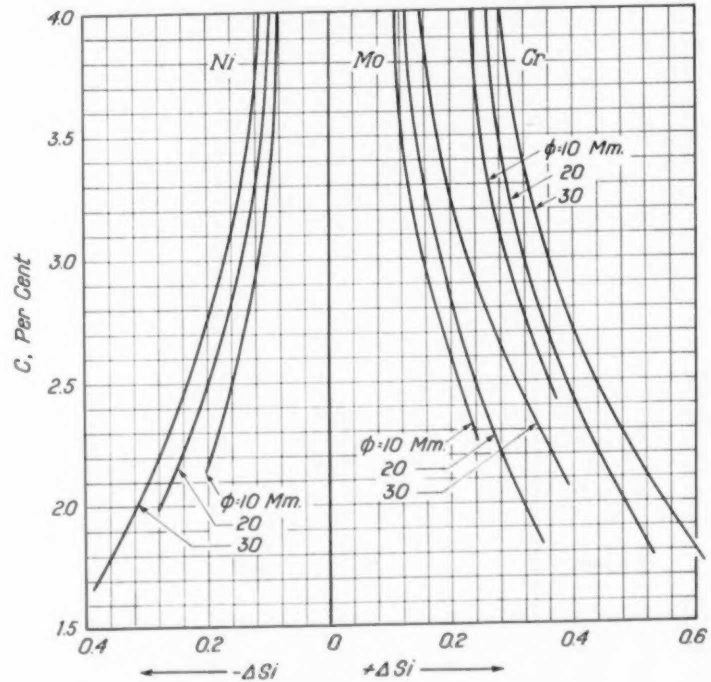
Curves Limiting the Pearlitic Zone for Cylindrical Test Bars 10, 20 and 30 Mm. in Diameter

Structural Diagrams for Alloy Cast Irons

Sheet II of Two Prepared by H. Laplanche, Citroen Works, Clichy, France







Values of the Shifting of Curves Toward the Left (Ni) or the Right (Mo, Cr), for 0.5% of Each Alloying Element. The shifting produced by an addition of 0.5% molybdenum or chromium is designated by $+\Delta Si$, and the shifting produced by 0.5% nickel is designated by $-\Delta Si$.

ABRASIVE WEAR OF METALS

By Roy D. Haworth, Jr.
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Although wear is one of the most prevalent reasons for metal parts becoming unserviceable, the factors causing wear and the means for combating it are not well understood. Present knowledge of wear is probably from 10 to 20 years behind advances in the study of corrosion.

Wear generally is classified into two main categories: *(a)* abrasive wear caused by extraneous and usually nonmetallic materials, and *(b)* metal-to-metal wear. Except for galling, which is caused by momentary adhesion and tearing apart of mating metals, the factors causing both types of wear may be similar in certain respects, although the performance of various metals may be radically different. A metal or treatment which provides excellent wear resistance under one set of conditions may not be beneficial under other conditions. This article is concerned only with abrasive wear.

The testing machine used to obtain the data discussed here was developed three years ago in the Metals Research Department of the Armour Research Foundation. The machine consists of a rotating rubber disk which carries loose abrasive material on its periphery against a stationary test specimen. A general view of the machine is shown in Fig. 1. The test specimens are held in a vertical position under load against the periphery at the far side of the disks shown in the photograph. Weight losses of the specimens are determined by weighing with an analytical balance before and after testing. A more complete description of the machine may be found in the ⊕ *Transactions*, Vol. 41, 1949, p. 819.

In tests with a rubber disk, friable abrasive grains are not crushed when carried between the disk and specimen. Results obtained with this device have correlated excellently with service applications in which crushing is not involved. With certain less friable materials, such as cast iron and steel shot, the use of a steel disk provides better correlation with service applications involving these materials.

Variable Factors in Abrasive Wear — The principal factors affecting the performance and extent of abrasive wear of metals are: *(a)* particle size, *(b)* hardness of abrasive, *(c)* degree of angularity or roundness of abrasive, *(d)* nature of the service (dry or wet), *(e)* speed, *(f)* pressure, *(g)* impact, *(h)* imposed heat and *(i)* corrosion.

The study of wear is further complicated because some of the above factors are interdependent. The effects of the more important variables are illustrated in the following sections.

Particle size of the abrading material affects the extent of wear to varying degrees, depending on the roundness or angularity of the abrasive grains. In order to avoid variable results, particles in the Tyler screen size range of 28 to 35 mesh are used for the abrasion research whenever possible. The reproducibility of results normally is within 10%.

Abrasiveness of Various Materials — Some of the existing confusion regarding abrasive wear stems from insufficient consideration of the nature of the abrading material. In general, abrasiveness increases with the hardness of the abrading material for a given particle shape. However, angular particles of a softer material may be more abrasive than rounded grains of a somewhat harder material. Abrasiveness further depends on the metal being tested as well as on the conditions under which the tests are made. The relative abrasion resistances of two different steels to several abrading materials are shown in Table I, p. 844.

Abrasive wear — the mechanical deterioration of metal in contact with nonmetal or abrasive — is an important factor in the performance of many metal products: for instance, jaw crushers, ball mills, impellers, plowshares, sandblasting equipment, mining machinery, earth-moving equipment, and conveyer screws for sand. This article concerns the effects of different abrading materials, speed, pressure, impact, moisture and heat on the wear of metals, especially hard steel and cast iron.

The aluminum oxide, in contrast with the other materials, is relatively more abrasive against the high-carbon high-chromium steel than it is against S.A.E. 1045. The fact that the weight losses produced by alumina and quartzite on 1045 steel are nearly equal does not mean that quartzite would be almost as effective as alumina for grinding carbon and low-alloy steels. The sharp grains of the softer material would become dull much more quickly than the harder grains if in the form of fixed abrasive grinding wheels; this is not indicated by the accelerated tests with loose abrasive particles. The results do indicate, however, that the high-carbon high-chromium steel would be much more resistant than the plain carbon steel to all of the abrasive materials tested, although to varying degrees. This variance is illustrated in the last column of Table I, which shows ratios varying from 1.9 to 41.5.

The abrasiveness of the pyrites and slate, which are encountered as gangue materials, helps explain the wear experienced in coal mining and handling equipment.

Although softer than Ottawa sand, the feldspar and pyrites are more abrasive against 1045 steel because of the multiplicity of sharp cutting points and edges. Against the more abrasion resistant high-carbon high-chromium steel, angularity of the softer abrading materials is less effective, probably because the sharp edges of the particles become rounded more quickly and resistance to their penetration into the steel, therefore, is greater.

Preliminary tests to determine the applicability

Fig. 1 — Abrasion Testing Machine

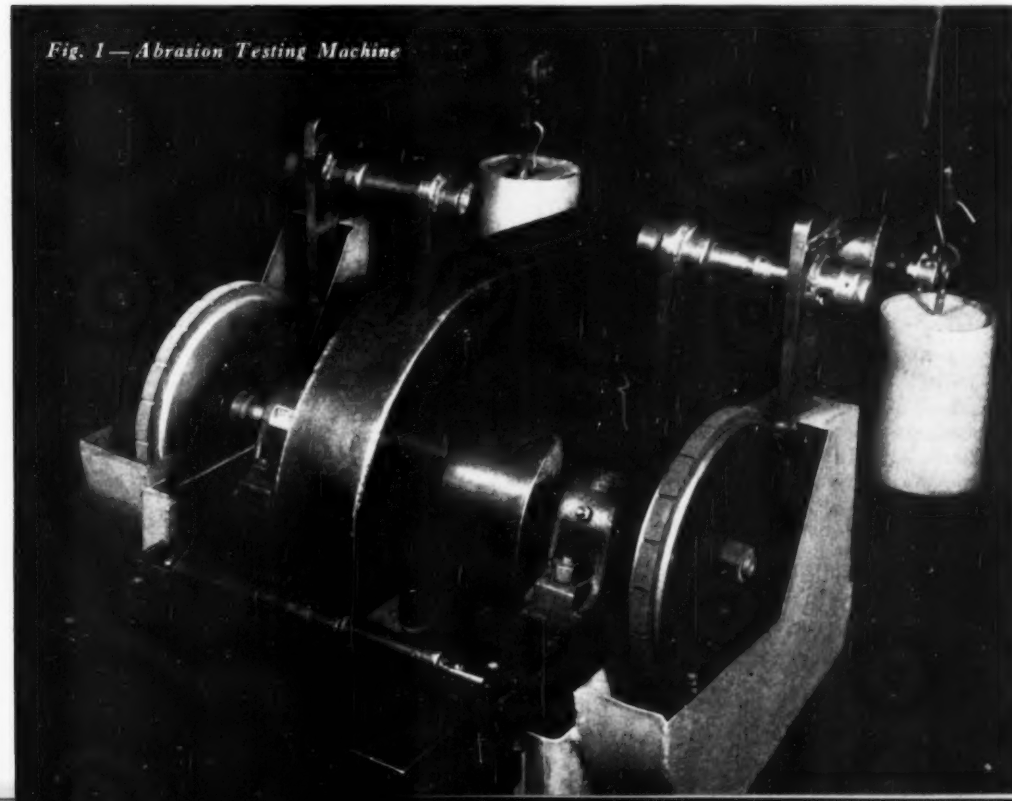


Table I — Abrasiveness of Various Materials

Abrasive Material	Mohs Hardness	Weight Loss (Grams × 10)		
		1045	C-Cr	Ratio*
Alumina	9	140	75.2	1.9
Quartzite	7	130	8.4	15.5
Ottawa sand	7	21	2.2	9.6
Feldspar	6	55	2.4	23.0
Iron pyrites	6–6½	32.8	3.5	9.4
Slate	—	19.2	0.8	24.0
Coke	—	16.6	0.4	41.5

Both steels were fully hardened: S.A.E. 1045, Rockwell C-59 to 62; high-carbon high-chromium steel (2.2% C, 12% Cr, 1% V), Rockwell C-64 to 67. All abrasive grains angular, except the Ottawa sand, which was round. Tests were dry; speed was 600 ft. per min.; load, 60 psi.; test distance, 4000 ft.

*Weight loss of 1045 steel divided by weight loss of high-carbon high-chromium steel.

of the abrasion testing machine for evaluating grinding abrasives revealed some interesting results. Dry tests were run with aluminum oxide and silicon carbide on a hardened high-carbon high-chromium steel and on a cemented tungsten carbide containing 6% cobalt. The silicon carbide cut the tungsten carbide readily, whereas the softer aluminum oxide caused only about one twentieth as much wear. On the other hand, the wear rate with aluminum oxide on the high-carbon high-chromium steel was five times greater than that with silicon carbide. To state these results in a different manner, the tungsten carbide was 200 times more effective than the alloy steel on a volume basis in resisting alumina abrasion, but only twice as efficient against silicon carbide. This suggests that tungsten carbide might be an effective and economical mold material for producing aluminum oxide grinding wheels but not for silicon carbide wheels.

Since both abrasive grains are angular, the poor performance of the harder silicon carbide in contrast with aluminum oxide against the toolsteel is puzzling. For grinding hardened toolsteels, aluminum oxide wheels likewise are superior to silicon carbide wheels.

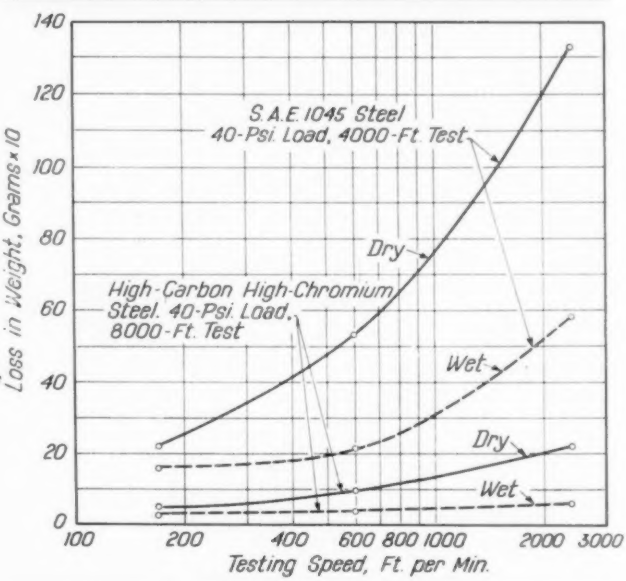
Effect of Speed in Dry and Wet Abrasion — Speed of the abrading material relative to the metal has been shown to be an important factor in affecting the abrasion resistance of metals in laboratory tests. Figure 2 shows the effect of speed in abrasion tests with dry and wet crushed quartzite on hardened 1045 and high-carbon high-chromium steels. The logarithmic plotting of the speed shows that the dry and wet results for each steel approach common asymptotic values at low speeds.

The losses in weight for both dry and wet tests increase with increase in testing speed, but at different rates. The increase in weight loss with speed is undoubtedly a temperature effect and is marked in the dry tests, particularly with the 1045 steel. Temperatures above 850° F. have been recorded by means of thermocouples in high speed (2400 ft. per min.) dry quartzite tests on hardened 1045 steel. The instantaneous surface temperatures are evidently much higher, as revealed by a considerable amount of sparking, which is not noticeable at lower speeds.

Bowden and Ridler* in England used as thermocouples two metals rubbed together at a relative surface speed of 2160 ft. per min. and under a load of 170 psi. In unlubricated tests, maximum surface temperatures above 1800° F. were noted. In the presence of lubrication under essentially the

*"Physical Properties of Surfaces", by F. P. Bowden and K. E. W. Ridler, *Proceedings*, Royal Society of London, Vol. 154, Ser. A, 1936.

Fig. 2 — Effect of Testing Speed on Abrasion Resistance



same test conditions, temperatures above 1100° F. were reached. These investigators state further that when metals and nonmetals are rubbed together, the instantaneous surface temperatures produced may be even higher. The development of high instantaneous contact temperatures even in the presence of the cooling effect of a slurry would explain the increased weight loss with speed in the wet quartzite tests.

The smaller increase in weight loss of the high-carbon high-chromium steel with increasing speed in Fig. 2 undoubtedly is a function of its superior hot hardness at the instantaneous temperature developed on the surface.

Hardness determinations were made on the worn grooves of hardened 1045 steel specimens after tests at surface speeds of 170, 600 and 2400 ft. per min. with both dry and wet Ottawa sand. The results are shown in Table II, together with estimated tempering temperatures required to produce the softening observed. The specimens from the wet tests showed no softening, indicating that the temperature effects in slurry abrasion must be confined to surface layers of very shallow depth. The superficial hardness values in Table II convert to values identical with those obtained by direct Rockwell C readings, indicating that surface layers of different hardness or structure, if any, cannot be detected by ordinary hardness measurements.

Table II — Hardness of 1045 Steel After Abrasion

Test Speed (Ft. per min.)	Test Condition	Rockwell 15-N	Rockwell C	Approx. Temp.
170	Dry	90 to 91	60 to 62	—
600	Dry	88 to 90	57 to 58	300° F.
2400	Dry	82 to 83	42 to 43	600
600	Wet	91	60 to 61	—
2400	Wet	90 to 92	60 to 61	—

Hardness determinations on grooves of worn test specimens after abrasion with Ottawa sand. Hardness before abrasion test, Rockwell C-60 to 62; test load, 40 psi.; test distance, 8000 ft.

In attempting to correlate laboratory data with field experience, it is not always necessary or desirable to run the tests at the speed involved in the service application. In the laboratory test, the heating effect is concentrated, whereas in service any point may be exposed only cyclically to the abrasive action. During the periods between successive exposures, the abraded surfaces have an opportunity to cool. For example, high speed pulverizer hammers operating at a surface speed of 18,000 ft. per min. effectively contact the material being ground for only a portion of each revolution. Therefore, the opportunity exists for the surface to cool sufficiently that correlation may be obtained with tests at much lower speed in the laboratory device.

Likewise, with sandslinger liners, excellent correlation has been obtained with dry laboratory tests at 2400 ft. per min., even though the sand is carried past the liners at 10,000 ft. per min. In this application, the abrasion is concentrated, but since foundry sands contain a low percentage of moisture, the cooling effect produced apparently is sufficient to compensate for the lower speed in the dry laboratory tests. Typical laboratory and sandslinger service results are given in Table III.

The effect of pressure is more difficult to analyze than that of speed. At the relatively low pressures involved in sliding abrasion where crushing of the abrading material does not take place, weight loss increases with pressure at a greater rate than direct proportionality. This lack of proportionality apparently is caused by the higher contact temperatures produced as the load is increased.

In grinding ores and similar materials in ball mills, rod mills and other crushing equipment, the applied pressures are in excess of the compressive strengths of the materials being crushed. The unit pressures on metal parts under sharp-edged particles of tough ores, therefore, are tremendous. In

Table III — Correlation of Service Data on Sandslinger Liners With Laboratory Abrasion Tests

No.	Composition						Treatment	Rockwell C	Service Data		Laboratory Data	
	C	Mn	Cr	Ni	Mo	V			Time*	Ratio†	G. × 10	Ratio†
1	0.40	1.55	—	—	—	—	Hot rolled	22 to 28	31	1.0	26.3	1.0
2	0.40	1.55	—	—	—	—	Water quenched	52 to 55	29	0.9	31.0	0.85
3	3.20	—	0.26	(White iron)			As cast	42 to 46	100	3.2	6.3	4.2
4	3.22	1.72	1.77	6.0	—	—	As cast	58 to 62	200	6.5	4.2	6.3
5	2.25	—	11.50	—	0.77	0.20	1825° F., air cooled	62 to 67	360	11.6	2.6	10.0

Sandslinger data were obtained in a commercial steel foundry. Laboratory tests were conducted with dry crude Ottawa sand at 2400 ft. per min., 40 psi., through a distance of 8000 ft.

*Time for equal weight loss. †Ratio of sample to that of No. 1.

some metals, notably white irons, the mechanism of wear may involve microspalling of massive carbides. Such spalling could explain the inferior performance of white-iron balls compared with forged and hardened steel balls in ball mill service, whereas under low-pressure sliding abrasion, the white iron is far superior. Actually penetration may be initiated to a certain extent in the matrix surrounding massive carbides. Nickel-chromium white iron (Ni-Hard) with a martensitic matrix performs better in ball mill service than white iron with a pearlitic matrix.

Impact

Impact, like pressure, can alter the order of performance of metals obtained under straight sliding abrasion. The use of white iron in dipper teeth or pulverizer hammers is not practical; the performance of a tough material such as manganese steel, which is much inferior to white iron under straight abrasion, is excellent under heavy impact conditions. The failure of a brittle material under impact may be caused by outright breakage or by progressive spalling either on a macro or micro scale. Little is known concerning the performance of relatively brittle materials under impact conditions insufficient to cause failure in a single blow. To specify materials for applications involving repeated impact, one suggested approach is to eliminate from consideration materials which will not withstand, in repeated laboratory impact tests, the degree of shock anticipated in service. Materials of sufficient shock resistance can then be further classified according to abrasion resistance under the conditions prevailing in service.

Imposed Heat

In certain applications such as forging dies, rolling mill rolls, and gas turbine blades, externally applied heat is superimposed upon frictional heat. Wear in forging dies and rolling mill rolls is caused by abrasion of hot scale; in gas turbine blades, by fly ash at temperatures in excess of 900° F. The formation of loose oxide layers, readily removed by the abrasive action, may contribute substantially to wear at elevated temperatures.

The amount of published information available on wear at elevated temperatures is negligible. Considerable hot hardness data have been accumulated but these may be misleading because the instantaneous surface temperatures, which are a summation of the heat imposed plus the frictional heat generated, may be much higher than the subsurface or steady-state temperature. Forging dies, for example, have been reported to show visible color in a dark room immediately after repeated use. For this much heat to remain in the dies, the instantaneous surface temperature may have been several hundred degrees higher.

Corrosion

Corrosion under mildly abrasive conditions or where exposure to severe abrasion is only intermittent is a factor to be considered in applications such as pumps used for handling acid waters carrying abrasive materials. The use of expensive but corrosion resistant hard facing alloys is justifiable in applications of this type. The corrosion factor, likewise, may explain the reported superior performance of high-chromium white irons over plain or low-alloy white irons under certain slurry conditions and not under others.

The problem is different from that under ordinary corrosive conditions because protective films which ordinarily would inhibit corrosion are continually being removed by abrasive action. To be effective under abrasive conditions, corrosion resistance must be inherent in the base metal.

Resistance to Sliding Abrasion

The resistance of metals to sliding abrasion depends on the hardness, form, size, amount and distribution of the harder microconstituents.

If the microhardness of one constituent of an alloy is higher than that of the abrading material, the abrasion resistance will increase with the hardness and amount of the hard constituent. Raising the carbon content of white iron, for example, from 2 to 3%, will substantially increase the abrasion resistance because of the increased amount of primary cementite present (Table IV).

Table IV — Effect of Carbon and Alloy Content on Dry Quartz Abrasion of White Cast Irons

No.	Composition			Rockwell C	Weight Loss (Grams × 10)
	C	Cr	Ni		
1	2.38	—	—	35 to 42	29.4
2	3.20	0.26	—	42 to 46	17.7
3	3.28	1.70	4.90	58 to 62	11.6

Test conditions: Speed, 600 ft. per min.; load, 60 psi.; distance, 4000 ft.

For a constant amount of primary carbide, the abrasion resistance of white iron can be increased further by adding balanced amounts of chromium and nickel to produce a martensitic matrix (see No. 3 in Table IV), which is harder than the pearl-

itic matrix of the plain white irons.

Importance of the size and distribution of the hard constituents can be illustrated by comparing the abrasion resistance of wrought high-carbon high-chromium steel with that of a similar cast alloy. In the cast alloy, the carbide is distributed poorly in the form of a continuous network, whereas in the wrought structure, it is much more uniformly dispersed (Fig. 3). The large exposed areas of matrix make the cast structure more vulnerable to abrasive attack as illustrated by the respective dry quartz abrasion values in Table V. Likewise, the carbide distribution and the abrasion resistance of rolled stock are dependent on the amount of reduction in rolling. Thus, heavy sections where the initial dendritic carbides are less thoroughly dispersed probably will have poorer abrasion resistance than lighter sections which have undergone a greater degree of reduction.

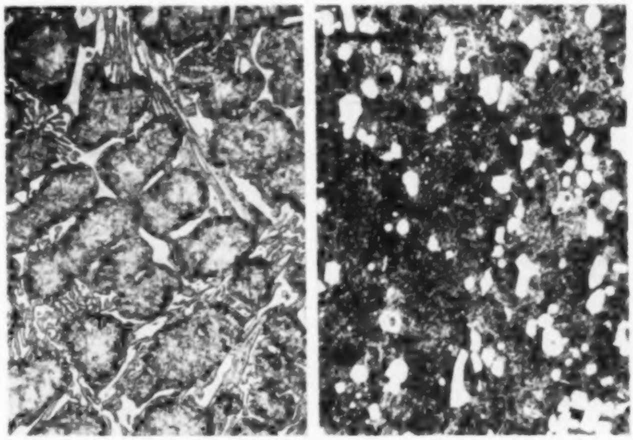
The effect of shape of the microconstituents on abrasion resistance can be illustrated by comparing cemented tungsten carbide with tungsten-titanium-tantalum carbide of identical cobalt content. The microstructure of straight tungsten carbide consists of angular grains, whereas mixed carbides of tungsten, titanium and tantalum have decidedly rounded grains. The influence of these structures on abrasion resistance is demonstrated in Table VI. Micrographs illustrating the structures but containing a larger amount of binder (approximately 12%) are shown in Fig. 4.

The triple carbide, although slightly harder than the straight carbide, is inferior in abrasion resistance. Because of the lower density of the triple carbide, volume losses indicate even poorer performance than the weight losses. The better performance of the tungsten carbide is probably due to interlocking of the angular grains, whereas the rounded grains in the triple carbide are dislodged more readily during the test.

Table V — Dry Quartz Abrasion of Cast and Wrought Alloys of Similar Composition

Material	Thickness	Composition				Rockwell C	Weight Loss (Grams × 10)
		C	Cr	Mo	V		
Cast	$\frac{1}{2}$ in.	2.21	11.72	0.83	0.22	62 to 65	15.7
Wrought	$\frac{1}{4}$	2.26	11.5	0.77	0.21	61 to 62	8.1

Test conditions: Speed, 600 ft. per min.; load, 60 psi.; distance, 4000 ft. Both alloys cooled in air from 1825° F., then tempered at 400° F.



Cast Wrought

Fig. 3 (above) — High-Carbon High-Chromium Steel. 500 ×

Fig. 4 (below) — Cemented Carbides. Etched with alkaline ferricyanide. 1500 ×. (From "Powder Metallurgy", A.S.M., 1942)

Tungsten carbide Tungsten-titanium-tantalum carbide

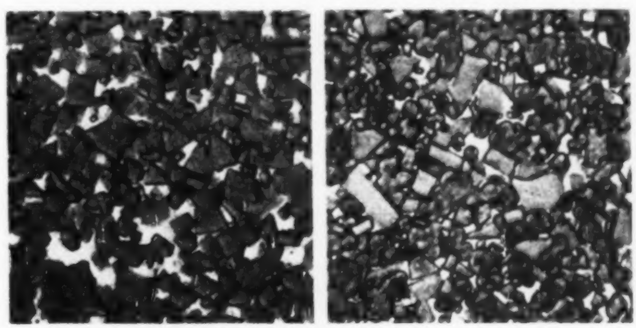


Table VI — Dry Alumina Abrasion of Cemented Carbides

Composition	Rockwell A	Weight Loss (Grams × 10)	Volume Loss
6 Co, 94 WC	89 to 90	7.1	0.05 cu.cm.
6 Co, 78$\frac{1}{2}$ WC, 11$\frac{1}{2}$ TiC, 4 TaC	91 to 91$\frac{1}{2}$	16.9	0.14

Speed, 600 ft. per min.; load, 60 psi.; distance, 32,000 ft.

Although some progress has been made in systematic studies of the factors causing abrasive wear and of the means to combat it, much more remains to be done. Fundamental studies under various conditions are required for a better understanding of the mechanism of wear.

Wear at elevated temperatures would be a particularly fruitful field for extensive investigation in view of the increasing number of high-temperature applications for metals. These applications impose more drastic requirements on conventional products. For example, the need is great for better die materials to resist the severely abrasive action encountered in forging the high-temperature alloys.

The factor of corrosion also warrants further investigation. Piston ring and cylinder wear in gasoline and diesel engines is undoubtedly a complex combination of corrosion, metal-to-metal wear and abrasive wear.

Materials for parts subject to abrasion in service should be periodically re-evaluated as operating conditions are changed. Because of the importance of speed and pressure, metals and heat treatments which were considered satisfactory in the past may no longer be suitable at higher operating speeds and loads.

X-RAY MICROSCOPES

By C. S. Barrett
Institute for the Study of Metals
University of Chicago

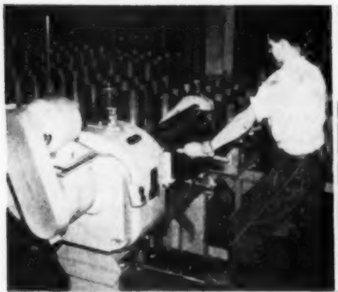
X-RAYS should furnish ideal radiation for microscopy because of their short wave length (100 to 10,000 times shorter than the wave length of light). Wilhelm Konrad Roentgen's conclusion that X-rays cannot be focused by lenses has not kept men from attempting X-ray microscopy. In fact, it was found that X-rays *are* refracted slightly, but only enough so that 100 lenses in series would be required to give a focal length as short as 100 meters. Even with beryllium lenses there would be very serious absorption in such a lens system; so the prospect of success along these lines is very remote.

There are other approaches to the problem that are more attractive. For example, the image can be made without focusing or magnification, and the image can then be recorded on film and subsequently enlarged. This is done, for example, in microradiography, where a shadow picture on fine-grained film is enlarged optically. It is also done in X-ray reflection microscopy, where a life-size image is made on film by the diffraction of X-rays (Bragg reflection).[1] Barrett has worked out a technique for getting useful magnifications of these reflected images up to 100 to 250 diameters and has discussed their applications to problems in physical metallurgy.[2] Micrographs prepared in this way show the places where inhomogeneous strain is concentrated and where fragments or lamellae are rotated from their normal orientation; recrystallized grains can be distinguished from cold worked grains, and imperfect from perfect grains.

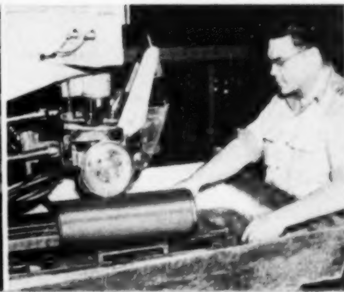
A "micro-analyzer" devised by Hámos approaches more nearly a true microscope, because crystal reflection is used to *focus* the X-rays. A cylindrically bent crystal is used to focus the rays on a film, and the image is then enlarged optically. Since the rays that are recorded in an image are of a single wave length in this method, it is possible to photograph the surface of a specimen in the "light" of one of its kinds of atoms, and thus to record by fluorescent radiation the segregation in the specimen. This X-ray micro-analyzer has successfully shown the distribution of metallic elements in minerals, but it has been used only for magnifications of 10 and 35 × and

(Continued on p. 890)

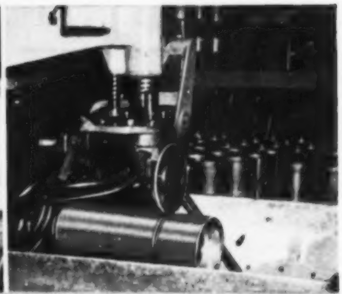
[1]References are on p. 891.



Rolling silicon bronze to the exact diameter before welding



Resistance welding of longitudinal seam



The bottom is resistance-welded to the shell

REVERE SILICON BRONZE IN RE-DESIGNED EXTINGUISHER

Everyone is familiar with the 2½ gallon fire extinguisher that is operated by turning bottom up. It is to be found in almost every factory, office and school. With it, countless fires have been put out, lives, property, jobs, money saved. Such a standard product tends to be taken for granted; most people naturally assume that it has reached its final perfection. Not so American-LaFrance-Foamite Corp., which some time ago decided to re-design its Alfco extinguishers in the light of the newest technological developments. To the user, the new extinguishers are definitely improved, being free from rivets, 4½ pounds lighter, and much more handsome. To the company, the product has been bettered in other ways, and is more efficiently produced.

Working out this extensive program required careful consideration of the relationships between design and materials, and materials, methods and machines. Alfco wished to abandon rivets and go to seam welding, among other things. Silicon bronze was selected as the material, because that can be easily resistance-welded, possesses strength of mild steel together with the corrosion resistance of copper. Revere and Alfco got together and jointly set up the time, temperature and pressure requirements for clean, sound welds. It was also necessary for Revere to establish the proper tempers for the body sheet so that it will more than withstand the Underwriters' pressure test, but still be formable into a cylinder with beads that locate the top and bottom domes. Similarly, tempers had to be selected for the sheet to be drawn into the domes. In all these and other activities the accumulated knowledge and experience of the Revere Technical Advisors, the welding section of the Research Department and of three Revere mills were used. Finally, the Research Laboratory tested the first production extinguishers to make sure that annealing practices were adequate.

Revere considers this an outstanding example of the benefits possible when a manufacturer and supplier collaborate on mutual problems. You are invited to consider Revere not only as a source of non-ferrous metals, but of know-how in their selection and fabrication.

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Sales Offices in Principal Cities, Distributors Everywhere.

The new Alfco Extinguisher, made by American-LaFrance-Foamite Corp., Elmira, N. Y.

PERSONALS

Roy G. Roshong ⊕ has resigned as product manager of the wire rod and bar sales division of Reynolds Metals Co. and is now with the American Saw & Tool Co., Louisville, Ky., as vice-president and production manager.

William H. Clark ⊕ is now a testing engineer with the Jeffrey Mfg. Co., Columbus, Ohio.

The A. F. Holden Co. announces the following executive changes: **J. B. Carey** ⊕, formerly sales manager, is now vice-president in charge of research and chemical manufacture; **C. R. Brown** ⊕, for the past 12 years in various sales capacities with the company, is now vice-president; **C. R. Hecker** ⊕ has been named sales manager for all Holden products.

Richard S. Smith, Jr., ⊕ has been promoted by Cook Induction Heating Corp., Maywood, Calif., to the position of general manager and vice-president.

Gerard H. Boss ⊕, formerly with the Naval Air Material Center, Philadelphia Naval Base, is now at the National Laboratory Division of the Carbide and Carbon Chemicals Corp., Oak Ridge, Tenn.

Sylvania Electric Products, Inc., announces the appointment of **Hugh Wainwright** ⊕ as sales engineer for the electronics division. With Sylvania since 1946, Mr. Wainwright was formerly a mechanical engineering specialist.

After graduating from Rensselaer Polytechnic Institute, **S. V. D'Andrea** ⊕ has accepted a position as welding engineer with the General Electric Co. laboratory at Pittsfield, Mass.

Mervin S. Allshouse, Jr., ⊕, formerly process engineer of the Carnegie-Illinois Steel Corp.'s Duquesne works, and student engineer with the National Tube Co., has been appointed metallurgical engineer at the Midvale Co., Nicetown, Philadelphia.

F. B. Dahle ⊕, formerly supervisor of the mechanical engineering division, has been appointed technical advisor at Battelle Memorial Institute, Columbus, Ohio.

Henry H. Mandle ⊕, in association with his son, Richard M. Mandle, and others, has organized Rare Earths, Inc., at Pompton, N. J., producers of cerium oxide and salts of other rare earth metals.

After nine years in the materials laboratory at the U. S. Naval Gun Factory, **Raymond B. Koehler** ⊕ has been transferred to the specifications unit of the research and development division, Office of Chief of Ordnance, Washington, D. C., where he is a materials engineer.

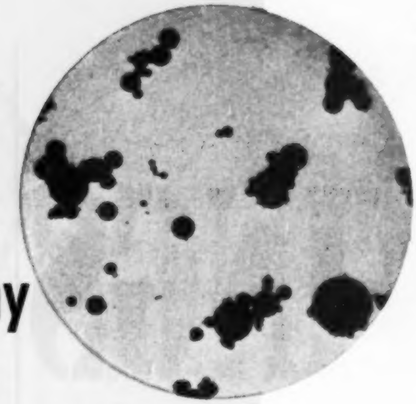
Thomas J. Kehoe ⊕, who was formerly with the American Potash & Chemical Corp., has joined the staff of Montgomery-Pomeroy, consulting chemists and chemical engineers in Pasadena, Calif.

R. H. Olmsted ⊕ has recently been appointed midwestern service engineer for Whitehead Brothers Co., New York. His headquarters will be in Conneaut, Ohio.

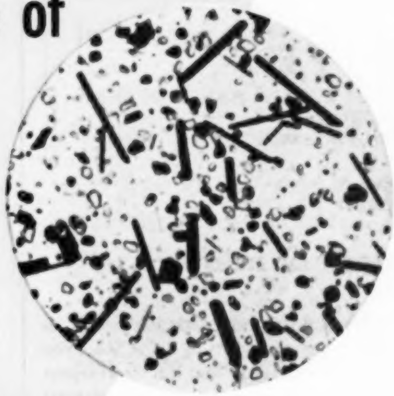
Bruce M. Shields ⊕ has returned to his former position as research metallurgist for the South Works, Carnegie-Illinois Steel Corp., after a year at the Kearny, N. J., research laboratory of U. S. Steel Corp.

Denton T. Doll ⊕, formerly with the Brush Beryllium Co., is now a member of the staff of the chemistry and metallurgy division of the Los Alamos, N. M., Scientific Laboratory of the University of California.

3 ways photography shows size and nature of particles



1 ELECTRON MICROGRAPHY —to identify and show size-frequency distribution of particles down to 1 millimicron. The photographic material to use is the Kodak Medium Lantern Slide Plate. The electron micrograph shown here is a 15,000X enlargement of silica smoke particles . . . a substance which has recently become available in commercial quantities. Among the uses for this material—believed to be one of the finest industrial particles—is that of aiding in suspension of other types of particles in liquids.



2 ULTRAVIOLET MICROGRAPHY —to study particles down to 70 millimicrons and to differentiate them by their behavior in the ultraviolet. The photographic materials to use are Kodak Metallographic Plates or, when images are weak, Kodak 50 Plates. The ultraviolet micrograph shown here is a 3000X enlargement of leaded zinc oxide particles (at 2750 Angstrom Units). In this case, ultraviolet illumination differentiates by showing lead sulfate as transparent and the zinc oxide as opaque, whereas in visible light, both are transparent.

3 VISIBLE LIGHT MICROGRAPHY—to determine the nature of finely divided particles down to 150 millimicrons. The photographic materials to consider are Kodak Metallographic Plates, with an ideal combination of speed, resolving power, and contrast characteristics; Kodak M Plates, where sensitivity to yellow and red light is required; and Kodak Panatomic-X Film, when you prefer to work with sheet film. The photomicrograph shown here is a 500X enlargement of commercial whiting.

FUNCTIONAL PHOTOGRAPHY

. . . is advancing scientific technics

Specific questions on choice of photographic materials for problems in identifying and measuring particles—or in any other branch of scientific or industrial photography—will be fully answered by correspondence.

Eastman Kodak Company, Rochester 4, N. Y.

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PERSONALS

W. D. Gilder has become associated with the Weatherhead Co., Cleveland, as metallurgical project engineer for the liquid petroleum gas tank division. He was formerly steel quality metallurgist for the Lorain, Ohio, works of the National Tube Co.

Carnegie Institute of Technology announces the promotion to full professorships of **Gerhard Derge** and **Frederick N. Rhines**. Both Dr. Derge and Dr. Rhines are in the department of metallurgical engineering and have been at the institute since 1934.

H. R. White, formerly with Bliss & Laughlin, Inc., has accepted a position as sales engineer with the Hy-Alloy Steels Co., Chicago, Ill.

The Ohio Ferro-Alloys Corp., Canton, Ohio, has announced the appointment of **Eric G. Skarin** as service metallurgist for the company. He was previously metallurgist at the Midvale Co.

Harold J. Babcock, formerly research engineer in charge of development and demonstration laboratories of Ajax Electric Co., is now technical advisor for metallurgy to the artillery ammunition division, Frankford Arsenal, Philadelphia.

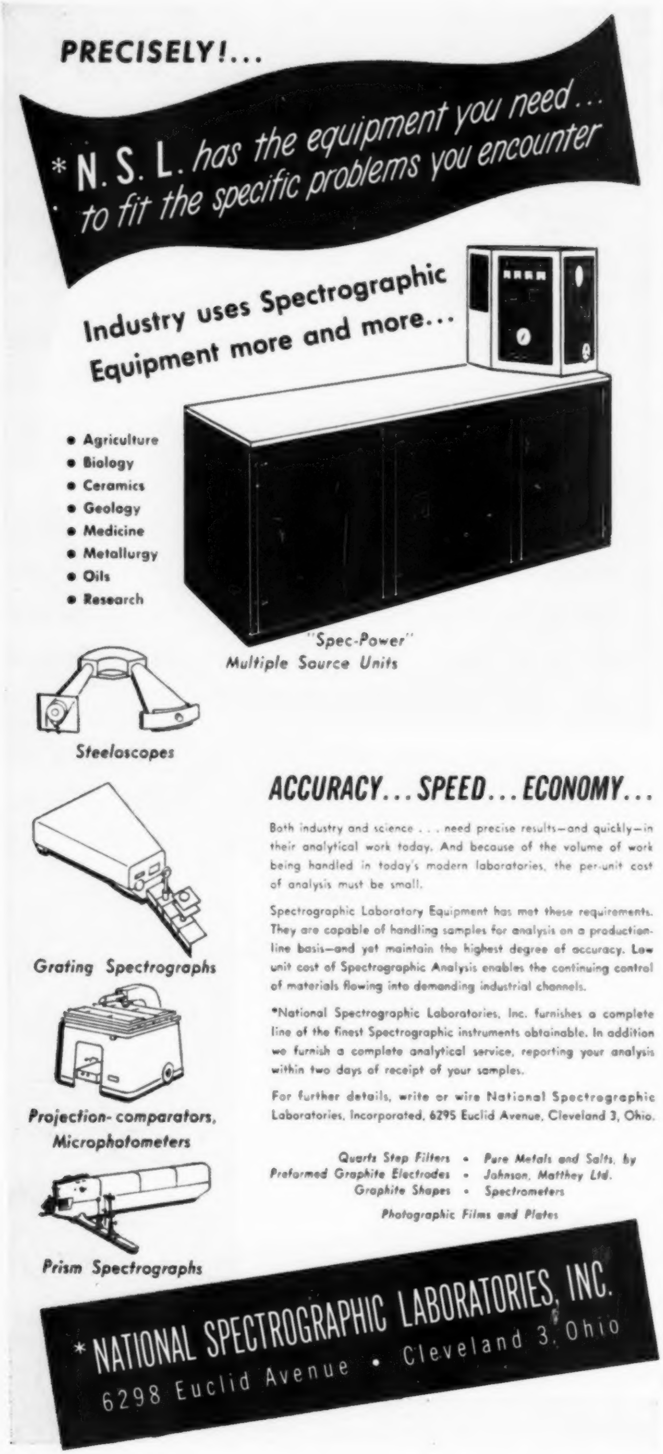
Kenneth T. Caplinger is now northwest representative of Western Die Casting Co., Emeryville, Calif. His office is in Seattle, Wash.

Formerly administrative head of LeTourneau Technical Institute, **Walter J. Brooking** has joined the engineering design department of the M. W. Kellogg Co., special projects division, Jersey City, N. J.

Charles C. Simpson, Jr., after completing work at the University of Alabama, has been assigned by the Air Force to the Guided Missiles Group, Elgin Air Force Base, Valpariso, Fla.

Following receipt of his B.S. degree from the University of Pittsburgh, **S. Bernard Messineo** has been appointed practice engineer with the Wheeling Steel Corp., at the Yorkville, Ohio, plant.

Lew F. Porter, for the past two years research metallurgist with the Chain Belt Co., Milwaukee, has recently accepted a position in the department of mining and metallurgy of the University of Wisconsin Experimental Station, Madison, Wis.



PERSONALS

National Supply Co. announces that **Ernest G. Unrath** ⊕ has been promoted to the position of works manager of the Ambridge plant of the Spang-Chalfant Division. Mr. Unrath's former position of general superintendent will be taken over by **S. H. Kilmer** ⊕, previously superintendent of inspection at the Ambridge plant.

Luther F. Taylor ⊕ has been transferred by Superior Steel Corp. to its New York City sales office from which he will be working the New England – New Jersey territory.

Alfred S. Kos ⊕ is now chief engineer with the Globe Stamping Division of the Hupp Corp., Cleveland.

C. R. Howarth ⊕, a recent graduate of Lafayette College, is now taking the loop course of the Bethlehem Steel Co.

Douglas P. Ferguson ⊕, formerly in the technical inspection department of Wilson Foundry & Machine Co., has joined the staffs of the department of chemical metallurgy and the department of metal processing of the College of Engineering, University of Michigan.

After finishing work for his M.S. at Purdue University, **Herbert W. Marsh** ⊕ has joined the Graver Tank & Mfg. Co., East Chicago, Ind., as a design engineer.

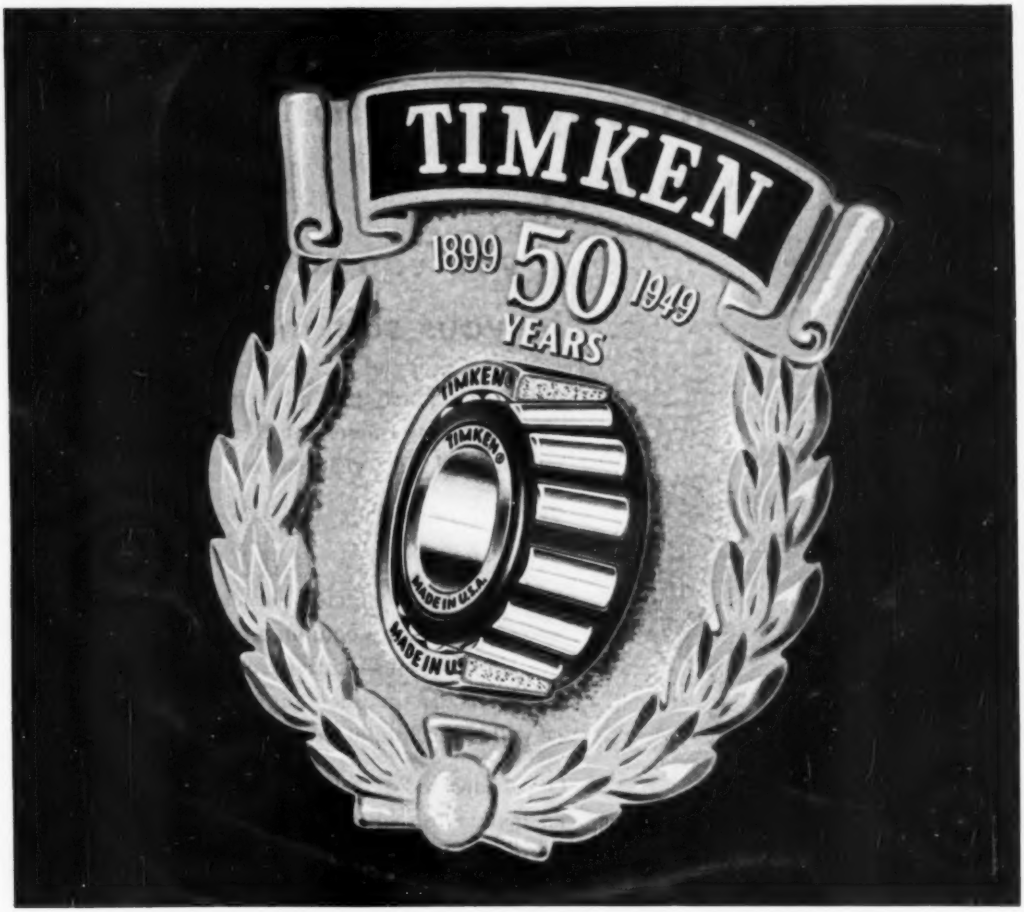
A. H. King ⊕ is now on active duty with the U. S. Army Corps of Engineers, assigned to an engineer construction battalion on Okinawa.

Eugene J. Kalil ⊕ is currently employed in the patent law department of the International Nickel Co., Inc., New York.

A. W. Mace ⊕, who retired from the Allegheny Ludlum Steel Corp. about one year ago, has established a consulting service in Washington, D. C., for steel requirements for the armed forces.

Samuel G. Russell ⊕, formerly assistant metallurgist of the Phosphor Bronze Smelting Co., is now metallurgist at North American Smelting Co., Wilmington, Del.

Dennard D. McCants ⊕ has resigned as design engineer for the U. S. Bureau of Reclamation, to accept a position as field engineer for the Cleveland Electric Illuminating Co.'s underground lines department.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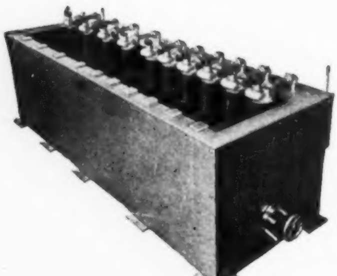

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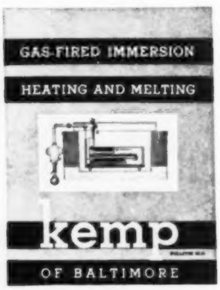

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HMP-6

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ATMOSPHERE GENERATORS • INERT GAS PRODUCERS • ADSORPTIVE DRYER SYSTEMS FOR PROCESS CONTROL

371. Alloy Steels

New 8-page engineering data bulletin describes Nitralloy, special alloy steel suitable for extreme wear and abrasion resistance. *Joseph T. Ryerson & Son, Inc.*

372. Alloys, Electronic

New 26-page booklet describes electrical and electronic properties of 18 high-nickel alloys. Cites typical uses and forms in which they are available. *International Nickel Co.*

373. Alloys, Fabricated

New catalog available showing cost-cutting fabricated heat treating equipment for higher pay loads and better quality. *Rolock, Inc.*

374. Aluminum Finishes

Attractive new 124-page booklet furnishes basic information on the various processes for applying surface finishes to aluminum. *Reynolds Metals Co.*

375. Ammonia

New 40-page booklet "Ammonia in Metal Treating" contains full details on pure ammonia with moisture and non-condensable gases eliminated. *Mathieson Chemical Corp.*

376. Band Filing

New DoAll band filer assures higher speed production in all types of precision filing work. Described in bulletin 48-400. *DoAll Company.*

377. Bits, Tool

Bulletin SL-2028 gives full details on high speed toolholder bits for all types of applications. *Firth Sterling Steel & Carbide Corp.*

378. Brazing

Easy-Flo simple, versatile method of fabricating ferrous, nonferrous and dissimilar metals described in bulletins 12-A and 15. *Handy & Harman.*

379. Brazing Alloy

Extruded Phos-Copper, the uniform brazing alloy for copper, brass and bronze, is discussed in new 15-page booklet along with recommended fluxes and "know how" of the process. *Westinghouse Electric Corp.*

380. Brushes

"Advantages of Carbon as a Brush Material", No. 13 in new series, contains brief history of the evolution of carbon as a current collecting brush. *National Carbon Co.*

381. Casting, Centrifugal

First detailed information on the Centri-Die process of centrifugal casting in permanent molds is contained in a new bulletin furnished on request. *Lebanon Steel Foundry.*

382. Castings

Bulletin 30 outlines a series of production and specification problems solved through use of Meehanite castings. *Meehanite Metal Corp.*

383. Castings

20-page booklet "Misco Precision Castings" contains valuable technical information for manufacturers requiring small, accurate alloy steel parts in quantity. *Michigan Steel Casting Co.*

384. Castings, Alloy

New bulletin, "Solving Corrosion Problems with Chem-Alloy High-Alloy Castings", features two important charts, a quick selector for corrosion resistance of most commonly used alloys and a list of types and grades in standard alloys. *Electro Alloys Division.*

385. Castings, Aluminum Alloy

Well-illustrated 80-page reference manual is now available with full information on the uses of Permite aluminum alloy castings. *Aluminum Industries, Inc.*

386. Castings, Steel

New table of classifications for steel castings groups them according to tensile strengths for easy reference. *Steel Founders' Society of America.*

387. Chromium-Iron

Properties and characteristics of 27% chromium-iron are comprehensively presented in 30-page bulletin TR-506. *Babcock & Wilcox Tube Co.*

388. Copper

New 63-page booklet in handy vest-pocket size contains a resume of interesting training lectures on Revere metals, their physical properties and countless uses. *Revere Copper & Brass, Inc.*

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Use the prepaid postcard on this page to obtain the helpful literature described on these two pages.

389. Die Castings

Revealing book "How Magnesium Pays" gives case studies of its economical use in a wide range of products. *Dow Chemical Co.*

390. Drawing Compounds

New leaflet available on several recently developed compounds made especially for use on different types of metals in stamping or drawing operations. *E. F. Houghton & Co.*

391. Fasteners, Aluminum

New stock list now ready with descriptions of over 500 kinds of aluminum screws, machine bolts, nuts and nails of rustproof material. *Central Steel & Wire Co.*

392. Finishes

Full details on black magic finishes for steel, iron, zinc, cadmium, copper and its alloys, given in new "Black Book". *Mitchell-Bradford Chemical Co.*

393. Finishes

Bulletin 1400 describes how the new Hydro-Finish provides cleaner, smoother surfaces prior to coating processes; saves hours on the production line. *Pangborn Corp.*

394. Fittings, Stainless

New informative technical bulletin, "Newscast", features reviews of technical literature, questions and answers culled from service engineering files. *Cooper Alloy Foundry Co.*

395. Flame Hardener

Attractively illustrated 20-page booklet gives complete details on new electronic universal flame hardener. *Stearns-Roger Mfg. Co.*

396. Forging

New 60-page well-illustrated catalog outlines the selection of metals for forgings and follows the various steps in production from blast furnace to finished forging die. *Drop Forging Assn.*

397. Forging

New 64-page booklet features pictorial review of forging operations on parts for freight cars, automotive, and farm implements. Facilities of two well-known forging plants described. *Pittsburgh Forgings Co.*

398. Furnace, Laboratory

New "Lab-Type" furnace with gas-tight retort offers self-contained unit of ample size for wide variety of lab operations. Fully described in bulletin F 327. *Boder Scientific Co.*

399. Furnace, Laboratory

New speed oven saves time and cost in laboratory drying. Leaflet describes how samples are dried twice as fast by hot, filtered air driven at high speed. *Harry W. Dietert Co.*

400. Furnaces

Bulletin 815-AB gives details for increased production economy with reciprocating furnaces. *American Gas Furnace Co.*

401. Furnaces

Bulletin 53 tells how new cyclone furnace can help reduce costs and improve quality of tempering, annealing, nitriding, and nonferrous heat-treating. *Lindberg Engineering Co.*

402. Gray Iron

Mechanical and engineering characteristics of gray iron, with details for designing cast components, all combined in new booklet furnished on request. *Gray Iron Founders' Society.*

403. Heating and Drying

New high-pressure steam fan heater described in bulletin 109. *Niagara Blower Co.*

404. Heating Elements, Electric

Bulletin H gives detailed information on AT type nonmetallic electric heating elements, including tables for a wide variety of sizes available. *Globar Div., Carborundum Co.*

405. Heat Treating

Form 7340 C, an 8-page illustrated article, contains interesting story of the conveyorized harden, quench, and draw installation at American Fort Pitt Spring Division. *Sunbeam Stewart Industrial Furnace Div.*

406. Heat Treating

Attractive two-color bulletin shows application of "Surface" burners to typical immersion heating installations. *Surface Combustion Corp.*

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

407. Immersion Heating

Bulletin 1E-11 provides attractively illustrated story on gas-fired immersion heating and melting operations. *C. M. Kemp Mfg. Co.*

408. Machine Parts

Illustrated Nitralloy data booklet lists many advantages of nitrided nitralloy for corrosion-resistant, surface-hardened machine parts. *Nitralloy Corp.*

409. Machining

Fundamentals of producing low cost machine parts — design, material and treatment — discussed in new 110-page "Three Keys to Satisfaction". *Climax Molybdenum Co.*

410. Melting, Induction

8-page illustrated article describes use of induction melting in improved technique for rotor-casting. *Ajax Engineering Corp.*

411. Metal Polishing

New convenient all-in-one specimen polisher and a mounting press adjustable to table top described along with other modern aids for the laboratory in new catalog. *Precision Scientific Co.*

412. Ovens, Baking

Bulletin 241 describes new industrial welding rod ovens and rod bakers for annealing, aging and tempering. *Carl-Mayer Corp.*

413. Potentiometers

Catalog 15-13 offers a complete description of electronic potentiometers, strip chart, circular scale and circular chart. *Brown Instrument Co.*

414. Potentiometers

Dynalog instruments for control of temperature, humidity, pressure, flow, etc. Details in bulletin 427. *Foxboro Co.*

415. Presses, Hydraulic

New 16-page bulletin No. 147 describes in complete detail the selection, operation and testing of hydraulic presses. *Lake Erie Engineering Corp.*

416. Pyrometer

New radiation pyrometer for instant spot temperature is described in catalog 100. *Pyrometer Instrument Co.*

417. Pyrometer

Catalog 1101-J describes how the new multiple-point Celectray controls up to six furnaces with the accuracy of a single-point instrument. *C. J. Tagliabue Corp.*

418. Pyrometers

Bulletin 1238 contains 56 pages of detailed information on thermocouples and includes a Buyers' Guide illustrating a complete line of instruments and accessories. *Bristol Co.*

419. Radiant Heaters

Description of the operation of all-metal Chromalox electric radiant heaters given in fully illustrated set of booklets. *Edwin L. Wiegand Co.*

420. Recorders

Condensed catalog Z6500 gives full description of Capacilog Recorder and other instruments for application in all types of laboratory classification. *Wheelco Instruments Co.*

421. Refractory Concrete

Detailed information furnished on methods of using refractory concrete in annealing furnaces. *Lumnite Div., Universal Atlas Cement Co.*

422. Safety Tools

Bulletin 119, new revised edition on safety hand tools, is conveniently and attractively designed for ready reference. *Ampco Metal, Inc.*

423. Salt Baths

Technical data sheets now available on Aerocarb and Aerocase for liquid carburizing and Aeroheat for salt-bath hardening of alloy steels. *American Cyanamid Co.*

424. Salts

New manual with more than 70 pages of material on heat treatment with molten salt baths. Fully illustrated. *E. I. duPont de Nemours & Co.*

425. Solders

Bulletin 45 gives full information on low-temperature silver solders. Samples sent on request. *American Platinum Works.*

426. Steel Sheets

Characteristic properties of US electrical steel sheets are shown in curve and tabular form in new, 180-page illustrated engineering manual No. 3. *Carnegie-Illinois Steel Corp.*

427. Steels, Alloy

Hardenability charts now available for many standard alloy-steel grades will help you to order steels with the proper hardness qualities. *Bethlehem Steel Co.*

428. Steels, Alloy

For full information on alloy steels with exceptional wear resistance and machinability, write for bulletin 91140. *Timken Roller Bearing Co.*

429. Steels, Stainless

Valuable new 32-page book, "Allegheny Ludlum Stainless Plates and Their Fabrication", now makes available all the data you need on sizes, types and uses of stainless plates, solid and clad. *Allegheny Ludlum Steel Corp.*

430. Steels, Stainless

Weekly lists with analyses of all plates in stock will keep you regularly informed on latest data. *G. O. Carlson, Inc.*

431. Steels, Stainless

Consistently fine stainless steels selected to resist nitric acid on the inside surface, and atmospheric conditions on the outside, write for more detailed information on Vancoram Ferro Chromium steels. *Vanadium Corp. of America.*

432. Steels, Stainless

Stainless mechanical properties for various forms and tempers are fully outlined in new data chart — Sec. A, No. 7. *Peter A. Frasse & Co., Inc.*

433. Surface Tester

GEC-311 scales provide 24 sample surfaces divided into ten degrees of surface roughness for quick calculations of finishes needed on machined parts. *General Electric Co.*

434. Tempilstiks

"Basic Guide to Ferrous Metallurgy", a plastic-laminated wall chart in color, is furnished on request. *Cloud S. Gordon Co.*

435. Testing

Simple, accurate, 34-inch-high machine provides speedy testing of tensile strengths up to 20,000 pounds. Literature available. *Detroit Testing Machine Co.*

436. Testing

Dependable, enduring microhardness testing made possible with the new "Tukon" tester, described in bulletin DH-7. *Wilson Mechanical Instrument Co.*

437. Thermocouples

Catalog 59-R tells complete story on use of Chromel-Alumel couples and extension leads. *Hoskins Mfg. Co.*

438. Thermocouples

A new 34-page catalog, Reference H, will furnish complete data on thermocouples, quick coupling connectors, thermocouple wire, lead wire, protection tubes, etc. *Thermo Electric Co.*

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371	388	405	422	439
372	389	406	423	440
373	390	407	424	441
374	391	408	425	442
375	392	409	426	443
376	393	410	427	444
377	394	411	428	445
378	395	412	429	446
379	396	413	430	
380	397	414	431	
381	398	415	432	
382	399	416	433	
383	400	417	434	
384	401	418	435	
385	402	419	436	
386	403	420	437	
387	404	421	438	

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MAGNETS FROM PURE IRON POWDER*

By Robert Steinitz
American Electro Metal Corp.

POWDER METALLURGY always becomes especially interesting when its products obtain properties which cannot be reproduced by any other mode of manufacture. Unusual characteristics often are obtained by a combination of materials which cannot be joined in any other way than by a mixture of the powders. A few years ago, however, some quite unique properties were found in a powder metallurgical product of a single metal — properties which were completely opposite to those of the solid material and which were limited to powders below a certain critical particle size. It was found that if iron powder of a sufficiently small particle size was compressed, the compact would have excellent permanent magnetic properties comparable with the best permanent magnetic materials obtained by standard alloying procedures. The particles had to be of colloidal size, that is, of a size between 1/10 and 1/5 micron or smaller, and, during the process of manufacture, temperatures and pressures had to be avoided which would make the particles agglomerate or the grains grow.

Magnets of this type have been produced since about 1946 by the Société d'Electro-Chimie, d'Electro-Métallurgie et des Aciéries Electriques d'Ugine, in Grenoble, France, and a large amount of theoretical work has been done at the University of Grenoble, France, especially by Prof. Néel.[1,2] It had already been discovered previously that the coercive force of powdered material depends on the particle size, at least to some extent, and a number of papers had been published concerning this. The U. S. patent of Dean and Davis[3] mentions the production of fine iron powder, and its use for permanent magnet material. Guillaud,[4] in his doctor's thesis, 1943, describes the dependence of the coercive force of an intermetallic compound, MnBi, on particle size; and Kittel[5] published a theoretical

(Continued on p. 860)

*First published in *Powder Metallurgy Bulletin*, Vol. 3, 1948, p. 124-127.
References are on p. 866.


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MAGNETS FROM PURE IRON POWDER

(Starts on p. 858)

paper in 1946 determining the maximum size of ferromagnetic powders which would still form "single domain" particles and therefore have permanent magnetic properties.

It was at first quite surprising to obtain permanent magnetic material from pure iron, which, in the cast and rolled state, is generally the ideal material for the opposite purpose; that is, it is magnetically soft. The theoretical explanation for this fact has been brought forward, especially by Néel,[1, 2] and Weil[6] in Grenoble, and by Stoner and Wohlfarth[7] in Leeds, who followed to some extent the fundamental ideas advanced by Kersten.[8] The effect is now fairly well understood, and it is known that, below a critical particle size, the particle shape is also of special importance to obtain permanent magnetic properties. Actually, it was found that magnetic measurements can be used to determine the size and shape of ferromagnetic inclusions in nonmagnetic materials (for example, ferrite inclusions in austenite), following the theory developed for these fine iron powders.

The only manufacturer known who produces permanent magnets from ultra-fine iron powders in fairly large commercial quantities is the Société d'Ugine in Grenoble, France. Other companies (some of them in this country) are using fine powders for magnetic recording tape, but, to the knowledge of the author, no publication has appeared, either on the production of the magnetic material or the powder. The Ugine company has obtained a number of patents[9, 10, 11] covering the production of the iron powder as well as of the magnets themselves. Although any iron powder of a suitable particle size can be used for the production of magnets, the Ugine company prefers to use powder made by the decomposition and reduction of certain iron salts. It is known, however, that extremely fine carbonyl powder and so-called Raney iron (which is usually used as catalytic material) is also usable. The Ugine company produces its powder by the decomposition and reduction of iron formates. Iron formate is made by dissolving iron scrap in formic acid at elevated temperature and precipitating the

(Continued on p. 862)

MAGNETS FROM PURE IRON POWDER

(Starts on p. 858)

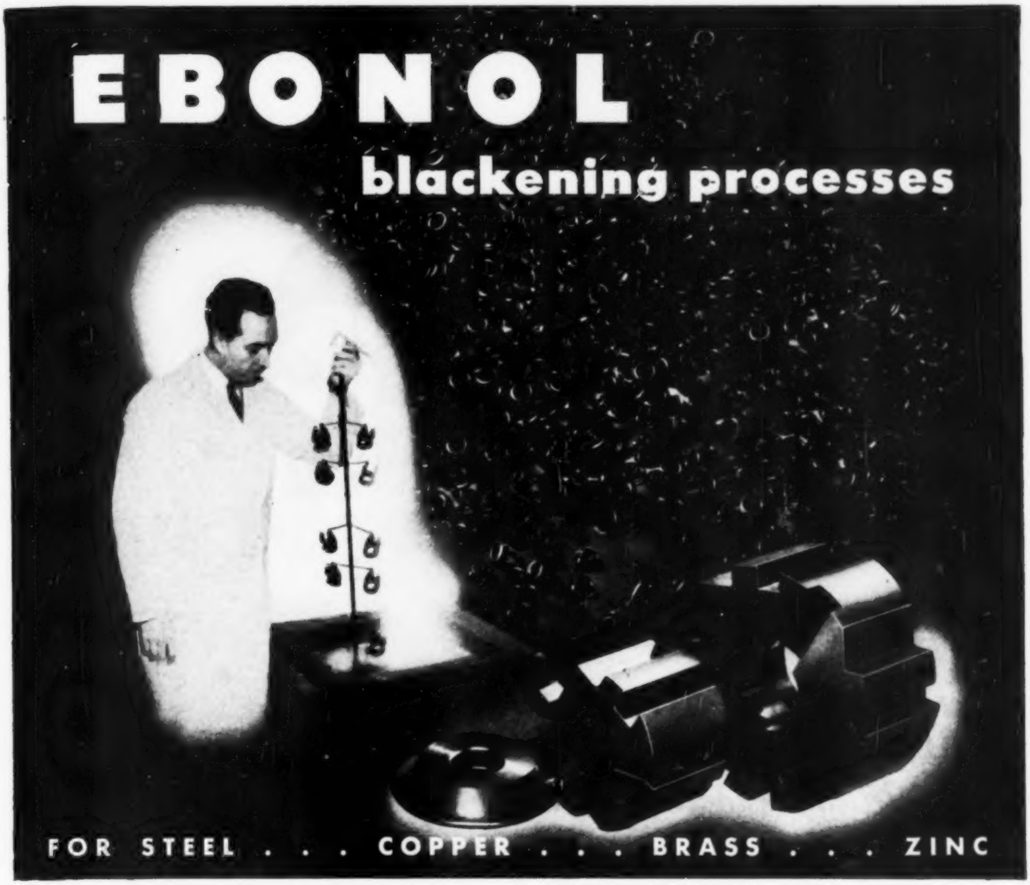
formate during cooling. Temperatures and concentrations have to be carefully controlled in order to obtain the correct particle size of the formate. In the second step, the formate is decomposed and reduced under hydrogen in special furnaces at a comparatively low temperature not exceeding 400° C. The products of decomposition and reduction have to be removed carefully in order to bring the reactions to completion. A higher temperature would make the very fine powder agglomerate and therefore lose the effect peculiar to it. After reduction, the powder is extremely pyrophoric, so that it cannot be removed from the furnace without protection. It has to be covered by a liquid such as benzene, ether, or acetone, within the cooling chamber of the furnace. The wet powder is removed from the furnace and pressed wet in hydraulic presses with about 30-50 tsi. pressure. Much higher pressures would destroy the good permanent magnetic qualities.[12]

The pressed magnets are either covered with oil to prevent any burning in air or immediately immersed in some organic or inorganic binding material which solidifies afterward and increases their coherence and prevents any possibility of oxidation. After this the magnet is finished, ready for magnetization and use.

Several such magnets are shown in Fig. 1, p. 864. It can be seen that complicated shapes are obtainable, that holes can be pressed into the magnet, and that it is even possible to press the powder around inserts which serve as shafts or holders of the magnets. The pressing can be done to very high accuracy so that no further machining is necessary to obtain the required tolerances. The application of pole shoes is difficult, but is often not necessary because complicated shapes can be produced directly by pressing.

The magnetic properties of the magnets are very good (Fig. 2). The Ugine company produces two kinds of magnets: One made of pure iron and one containing 30-35% Co, which is added during production of the formate. The magnetic properties of the cobalt-containing material are somewhat higher, but the use of so much cobalt as alloying

(Continued on p. 864)



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MAGNETS FROM PURE IRON POWDER

(Starts on p. 858)

ingredient is expensive and often not justified. The magnetic properties compare well with the average

Fig. 1 — Iron Powder Magnets Produced by Société d'Electro-Chimie d'Ugine. (Magnets are shown at about half size)

grades of Alnico, and can be slightly varied by changing production procedures to correspond closely with

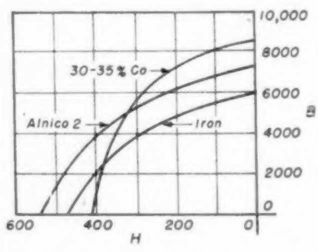

Fig. 2 — Magnetization Curves for Pure Iron and Iron-Cobalt Powder Magnets

one or the other of the Alnico grades.

The magnets are quite weak mechanically and, at the present time, this limits the field of their appli-

(Continued on p. 866)

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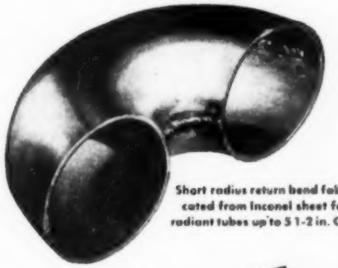

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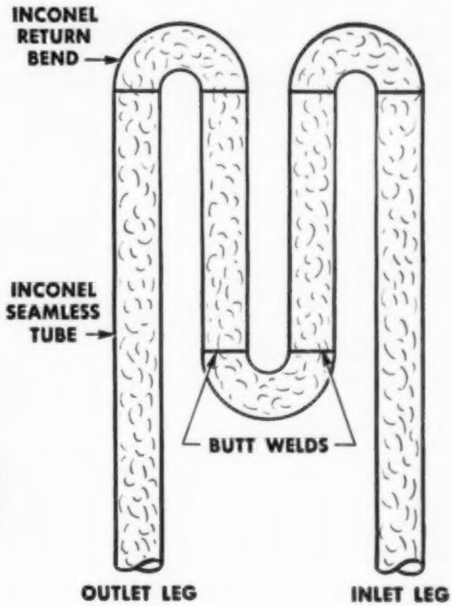

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MAGNETS FROM PURE IRON POWDER

(Starts on p. 858)

cation. It is possible to improve the mechanical strength about four or five times, by a heat treatment between 300 and 450° C.,[13] which, however, slightly decreases the coercive force and increases the residual magnetism, without changing the energy value. Temperatures above 700° C. destroy the permanent magnetic properties.[12] By the use of better infiltrating and binding materials, it will undoubtedly be possible to improve the mechanical strength for future applications.

It is interesting to note that the production method used for this fine iron powder is applicable to other metals, as well as certain alloys, such as tungsten-copper or iron-nickel-copper for use in products other than permanent magnets.[14] The tungsten-copper material is especially suitable for electrical contacts where, because of the fineness of the powder, the mixture of copper and tungsten is especially homogeneous. These extremely fine powders promise interesting results in future work. Problems, such as minimum particle size obtainable and its effect on the mechanical properties of compacts, as well as low-temperature sintering procedures which retain most of the particles in the small size, will have to be solved theoretically as well as experimentally. There is no doubt that new properties will be discovered if these powders are more readily available, and if their behavior is better understood. The production of permanent magnetic materials from fine iron powders is actually only the first step in the development of a new branch of powder metallurgy.

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7. E. C. Stoner and E. P. Wohlfarth, *Transactions of the Royal Society*, London, A, Vol. 240, 1948, p. 599.

(Continued on p. 868)

MAGNETS FROM PURE IRON POWDER

(Starts on p. 858)

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9. British Patent 590,392 (Convention date April 7, 1942).

10. British Patent 594,681 (Convention date July 26, 1944).

11. British Patent 596,875.

12. L. Weil, International Powder Metal Conference, Graz, 1948. (Summarized in *Metal Powder Reports*, Vol. 2, 1948, p. 190.)

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EFFECT OF BAINITE ON PROPERTIES*

THIS PAPER attempts to correlate the mechanical properties of a chromium-molybdenum steel with the nature and origin of the various microstructures obtained from the decomposition of its austenite, both isothermally and under several conditions of continuous cooling. Particular attention is devoted to the bainite structures, in an attempt to explain their reportedly superior high-temperature creep characteristics.

The steel chosen for study contained 0.15% C, 1.12% Cr, 0.80% Ni, and 1.05% Mo, along with the other usual elements. Its isothermal transformation diagram, determined microscopically, is characterized by two transformation rate maximums, the pearlitic at 700° C. and the bainitic at 400° C. Between these two ranges there is the usual narrow temperature zone, around 600° C., in which the austenite is extremely stable. The heat treatments included: *(a)* water quench, *(b)* oil quench, *(c)* air and furnace cooling, all followed by tempering between 300 and 700° C., *(d)*

(Continued on p. 870)

*Abstracted from "Effect of Bainitic Structures on the Mechanical Properties of a Chromium-Molybdenum Steel", by U. Wyss, *Von Roll Mitteilungen*, Vol. 7, 1948, p. 51-70.

EFFECT OF BAINITE ON PROPERTIES

(Starts on p. 868)

isothermal decomposition at 400° C. Isothermal and continuous cooling diagrams are shown in Fig. 1.

Water quenching resulted in complete transformation to martensite. Oil-quenched specimens contained from 10 to 20% bainite, which formed at about 400° C. During air cooling, transformation began at 485° C. (dilatometric measurements) with the separation of

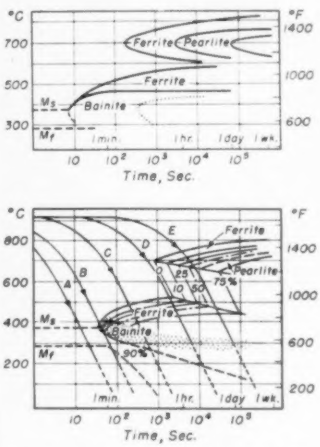

Fig. 1 — Isothermal Transformation Diagram (above) and Continuous Cooling Transformation Diagram (below) for Steel Containing 0.15% C, 1.12% Cr, 0.80% Ni and 1.05% Mo. Continuous cooling curves A, B and C refer to the cooling of 20-mm. diameter specimens in water, oil and air, respectively. Curve D is for air cooling of 100-mm. square specimens, and E is for furnace cooling.

pro-bainitic ferrite, accompanied by carbon enrichment in the austenite. The greater part of the retained austenite remained undecomposed even at very low temperatures (−180° C.), which effect the author attributes to carbon enrichment and to the well-known "stabilizing" phenomena discussed by other investigators during the past few years. On furnace cooling, propearlitic ferrite began to separate out at 750° C., enriching the austenite from 0.15 to 0.40% carbon. At room temperature the specimens contained about 20% residual aus-

(Continued on p. 872)

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EFFECT OF BAINITE ON PROPERTIES

(Starts on p. 868)

tenite, which required 2 hr. at 700° C. to decompose fully; 100 hr. at 600° C. was insufficient.

The microstructural changes resulting from tempering between 300 and 700° C. for various periods of time are described and discussed in great detail. These are supplemented by, and correlated with, studies on yield point, yield strength, tensile strength, elongation and creep. All specimens showed an increase in hardness (secondary hardness) when tempered near 500° C. The tempering temperature corresponding to the maximum secondary hardness shifted toward higher values as the cooling rate was decreased. Air-cooled specimens developed higher hardness values at certain combinations of tempering temperature and time than did water-quenched or oil-quenched structures.

As for tensile properties, the all-martensite structures had the highest yield point; with increasing amounts of bainite, pro-bainitic ferrite, pro-pearlitic ferrite, and retained austenite, the yield point gradually decreased. Close correlation was found between microstructure and the presence or absence of a true yield point. Thus, martensitic structures developed a definite yield point only after 10 hr. at 600° C. or 1 hr. at 700° C.

Martensitic structures and those containing small amounts of bainite after tempering between 600 and 700° C. had the lowest creep strength at 500° C. The creep strength increased as the amounts of bainite and pro-eutectoid ferrite increased (air and furnace cooling).

The author's summarizing graph shows that various structures tempered to a tensile strength of 142,000 psi. (measured at room temperature) had different limiting creep strengths at 500° C., as follows (values interpolated): oil quenched, 27,500 psi.; water quenched, 29,000 psi.; austempered, 43,000 psi.; air cooled (20-mm. diam.), 53,000 psi.; air cooled (100-mm. square), 61,000 psi. At a room-temperature tensile strength of 115,000 psi., the creep strengths at 500° C. were in the same order, varying from 22,000 to 48,000 psi. All these values were taken from the author's graphs of limiting creep strength versus tensile strength.

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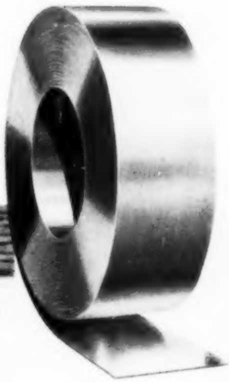

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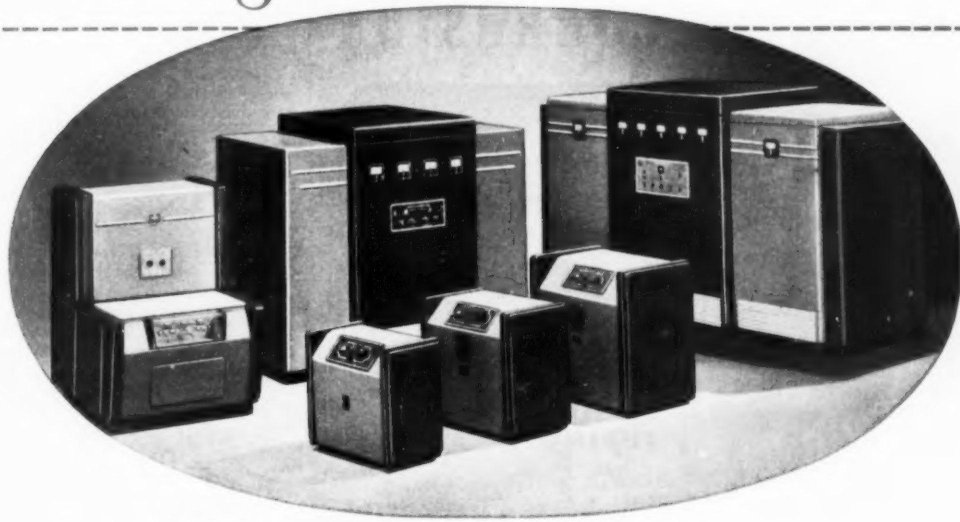

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EFFECT OF INCLUSIONS ON FATIGUE*

CERTAIN specifications for steel products contain a clause that the steel shall be free from excessive nonmetallic inclusions. Inspectors are gravely concerned as to what interpretation should be placed on the word "excessive" in the various specifications, particularly because experimental work on the effect of inclusions on the fatigue strength of steel has often led to apparently contradictory results.

In this paper, the authors have made a systematic attack on the problem, both experimentally and theoretically. Their results go far toward providing a rational method of predicting the effect of inclusions on fatigue strength.

In the experimental portion of the investigation, they used torsion and flexure fatigue tests to study the effect of inclusions on test pieces cut from large forgings made from molybdenum-vanadium and nickel steels. The test pieces were cut so as to provide typical groupings and types of inclusions. The authors' conclusions were:

1. Longitudinal inclusions do not significantly reduce the flexural fatigue strength of the steels tested when such inclusions are parallel to the direction of stress.
2. The same type of inclusions can reduce the torsional fatigue strength as much as 25%.
3. When the long inclusions are arranged in random patterns, they can be quite damaging.
4. Small globular inclusions do not lower the fatigue strength significantly.

In the theoretical portion of the paper, the authors used Neuber's method of analysis to provide a basis for understanding the experimental results. By means of this analysis, they demonstrated that:

1. As the size of globular inclusions becomes very small, the stress concentration factor produced by the inclusions also becomes small. This explains why tiny inclusions do not produce much effect.
2. The stress concentration factor associated with larger inclusions

(Continued on p. 876)

*Abstracted from "Effects of Inclusions on the Endurance Properties of Steels", by William C. Stewart and W. Lee Williams, *Journal* of the American Society of Naval Engineers, Vol. 60, 1948, p. 475-504.

EFFECT OF INCLUSIONS ON FATIGUE

(Continued from p. 874)
tends toward a limit as the inclusions become larger. This explains why the fatigue strength is relatively insensitive to the size of inclusions.

3. The orientation of the inclusions with respect to the direction of stress affects the stress concentration factor. This explains why longitudinal inclusions damage torsional fatigue strength.

4. Above a given size of shaft, the stress concentrating effect of a notch is relatively independent of the shaft size. This result suggests that in large forgings it is necessary only to treat inclusions or other types of notches as shallow defects independent of the size of part.

While the paper represents another step toward a more complete understanding of how steel should be selected and used, the authors point out that we are not yet ready to write rigid specifications on the acceptable limits for nonmetallics in large forgings. They also emphasize the fact that flakes may be much more damaging than the nonmetallics, and may often be a cause for rejecting forgings, regardless of the inclusions present. L. R. JACKSON

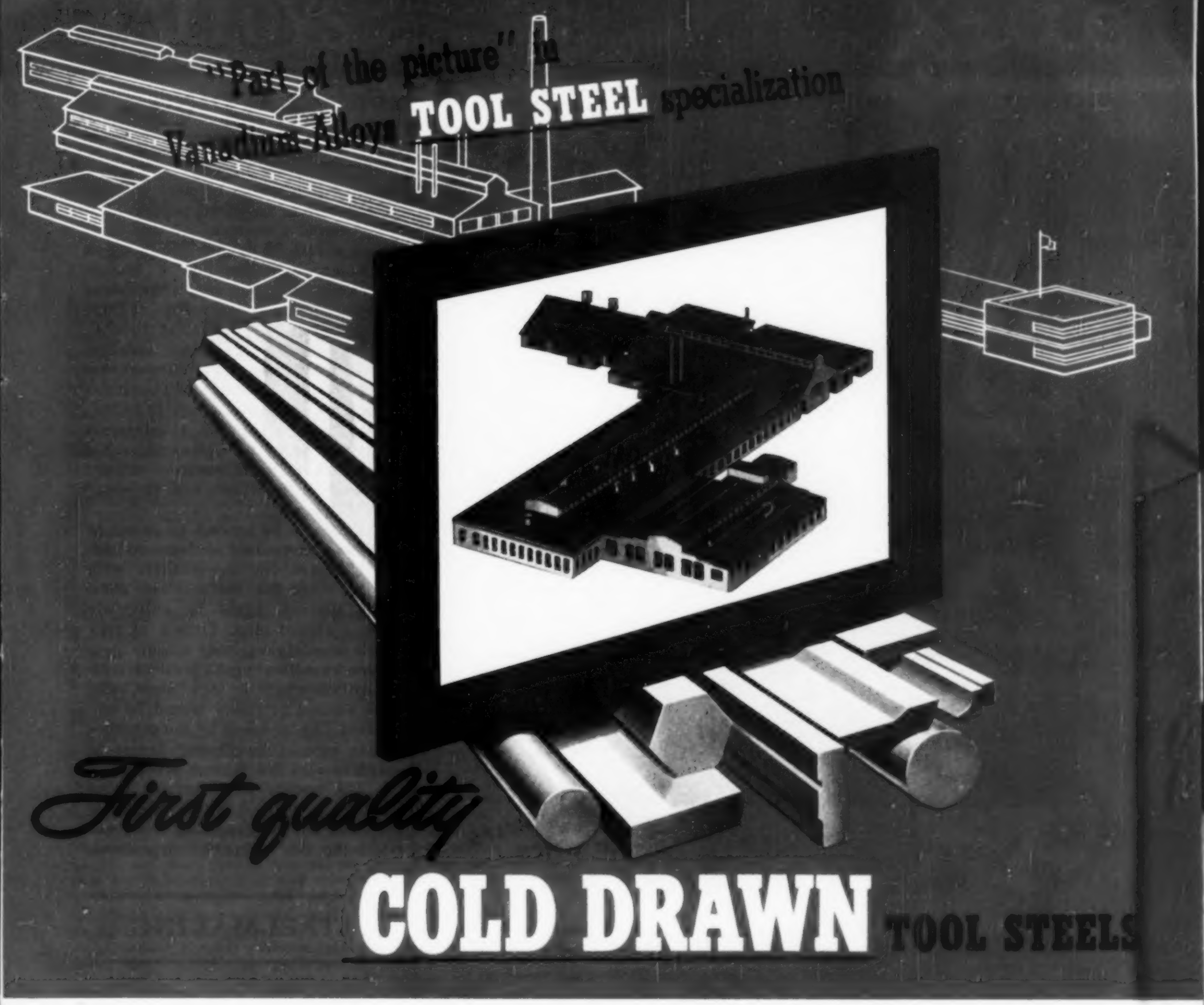
CLADDING*

THE word "plattieren" in German technology means the art of obtaining bimetals by the simple expedient of pressing together two metals capable of intimate atomic contact at an appropriate temperature and under a sufficient outer pressure, until the adhesion forces reach their maximum.

In this article the author enumerates all types of cladding, principally the one just mentioned, and also those based on brazing, soldering, pouring one liquid metal on the surface of another, passing one metal through a molten bath of the second metal, electroplating, and so on. He examines in some detail only the joining of copper to steel

(Continued on p. 878)

*Abstracted from "Further Developments in Cladding", by W. Engelhardt, *Zeitschrift für Metallkunde*, Vol. 34, 1942, p. 12-16.



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FIRST QUALITY TOOL STEELS

CLADDING

(Continued from p. 876)

and of two pieces of steel with an intermediate layer of copper. Experimental specimens of this kind with a disk of copper 1 mm. thick between can develop a tensile strength of 55,000 psi. after being prepared under a pressure of 7000 psi. applied for 1 min. at 1000° C.

The author examines qualitatively the influence of different factors on the adhesion and concludes that only the temperature is important; there is always a minimum below which no adhesion takes place. For the adhesion of copper to iron that minimum is about 850° C.

Pressure is needed in order to deform the contact surfaces enough to conform one to another; with clean, truly flat surfaces the pressure needed might be extremely low — almost zero. Time is of very little importance; one minute produces results almost identical with those obtained in one hour, and one second probably would be sufficient. An increase in temperature takes care of insufficient fitness of surface and insufficient pressure.

The author demonstrates some articles produced by this method of pressure welding, but does not describe the industrial procedure.

STEELMAKING

(Continued from p. 837)

important factors are charging time; melt-down carbon; time between finish of charging to hot metal, time first to second hot metal, and time between hot metal to first test (the shorter the better); burnt lime additions (heavy or late additions are harmful). Light bar scrap helps production, heavy scrap retards it. Production naturally increases with higher temperature of hot metal and higher fuel rate.

What is being done to improve scrap quality and prepare it better for charging? Your best hope is to increase its density. How? Bundle it better or cut it smaller. Figures showing the change in density were reported by H. A. Parker, superintendent of No. 2 openhearth, South Works of Carnegie-Illinois. In one cold melt operation 32 buggies per

(Continued on p. 880)

Q-ALLOYS THE QUALITY NAMES IN ALLOY FOR HEAT CORROSION ABRASION X-ite

A DAY WITH OUR NAVY IN THE PACIFIC

Attending the AMERICAN ORDNANCE ASSOCIATION Los Angeles meeting we enjoyed an unmatched and unforgettable experience as a guest of our Navy. We went to sea on the U.S.S. VALLEY FORGE (CV-45) Flagship of the First Task Force in simulated action against submarines, radio-controlled aircraft and dive bombers, firing live ammunition, leading a Battleship, Carriers, and Destroyers against the "Enemy".

Many "shutter-bugs" brought cameras, and were richly rewarded. We got two hundred color shots with Contax and Stereo Realist (3rd dimension). When we were "shooting" the anti-aircraft battery in action (see photo) another one directly under us opened up, blurred our .01 sec. shots. .005 sec. stopped the action. The 5" guns opening up rattled us into a double exposure. (The sharp photos here are official Navy. The others are B.&W. photos of 35 mm. color slides projected on a slide viewer.)

Impressive was the elevation of 32 fighters (from the hangar-holds on two giant elevators) to the flight deck and their rapid-fire take-off, a masterpiece of *Teamwork*. (Photos, before & after.)

Two catapulted Jet planes, a helicopter taking off, a Submarine running with a "Snorkel" and firing torpedoes across our bow, Radio-Controlled target planes providing "live" targets, Jets zooming us, and Dive-Bombers operating with *magnificent precision*. That was the spectacular stuff, OUR Navy showing her TEETH.

Behind all this is the world's most complex organization of men and material. No human achievement approaches the complexity, embraces the skills, or requires the co-ordination in operation as does a great ship, and OURS are *GREAT SHIPS*. First to give credit to American Industry, Labor, for their part in creating OUR NAVY are her Officers and Men, *those who render greater service for less*. These men are quite human, from career "Ratings" to "Big Brass"—they want good tools, kept SHARP. They're air minded, but they remember the job of transporting millions of men and many tons of material per man. They also remember that our Submarines destroyed many times more enemy shipping in the Pacific than our planes.

The Navy's greatest achievement is building MEN. If you haven't thought that through, look around your own plant, your own neighborhood, possibly your own family, and you'll agree that OUR Navy has Trained, Educated, and Developed MEN, not to a "Pattern", but to a broader use of their talents and capacities, a higher, more mature idealism, to excel in TEAMWORK.

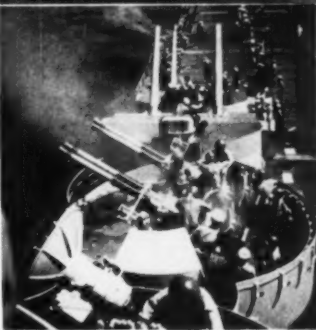
Old Sea-Dogs *do* learn new tricks. There are lots *left to LEARN*. Of CHANGE, alone, are we CERTAIN. We must ADVANCE to MEET IT, by AIR, by SEA, by Land. In our Laboratories, Colleges, Plants, OUR Navy is carrying on RESEARCH and DEVELOPMENT. Navy personnel, in Uniform and out, Physicists, Metallurgists, Chemical and Electrical Engineers, are working shoulder-to-shoulder with Naval Strategists, Master Shipbuilders, Pilots and Submariners, and all are advancing our U.S. Industrial future as *surely as advancing scientific, technical, and operational KNOW-HOW expedites ECONOMIC and SOCIOLOGICAL ADVANCE.*

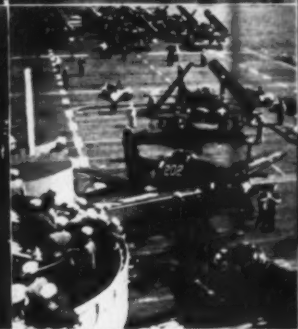
We believe that man for man, Officers, Enlisted and Civilian Personnel, Our Navy is unequalled by any organization anywhere, and we're counting the Hams, the politicians, the phoneys, and the "Rabbits" on *both sides*. One reason why we've taken Research and Development Contracts for the Services without profit—we share their objectives.

From our own small experience, we feel closer kinship with Flyers, and Seamen, but the Top Heroes of our Youth and of later years remain the same. To those LEADERS among Fighting Men who Top their Profession in all Services—who, crowding sixty, keep on flying, who LEAD AMERICA TO PEACE OR VICTORY—we accord our RESPECT and ADMIRATION.

Typical of such men is Vice Admiral Gerald F. Bogan, Commandant of the First Task Force, U.S. Navy. (Photo right). Officers and Men are proud to serve under him. (And tell you about it.) They don't come any tougher, or more "Regular", than "Jerry" Bogan. There are, Thank God, lots of "High Brass" like him, Directing the DEFENSE OF AMERICA, in ALL of our Fighting Services, keeping US STRONG for PEACE. And don't worry about the Kids, either, they're in-there-PITCHING, with Fine Morale, and High Purpose. That day at Sea with OUR Navy makes us Prouder-than-ever of being AMERICAN.

P.S. We're clear out of space and forgot to "peddle" our Alloys. Maybe you M.P. Readers will keep on buying 'em anyway. H.H.H.





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THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

STEELMAKING

(Continued from p. 878)

heat was the rule in 1942; it was increased to 43 in 1948. Savings in heat time up to 1½ hr. are also realized by using improved preparation methods. Alligator shears, hydraulic bundling, and larger oxy-acetylene equipment are making important contributions. Blowpipes using powders in addition to the cutting flame are in use on heavy pit scrap. The design of furnaces for cold metal shops is largely influenced by bulky scrap; larger chambers with higher roofs are required.

Acid Melting Techniques

The acid openhearth men held an open debate session, where lead-off men presented the case for the affirmative of the following five propositions:

1. Metal fluidity for a given steel is a function only of temperature. (Guy M. Neagley, Jr., assistant steel metallurgist, Pittsburgh Rolls Division, Blaw-Knox Co.) Fluidity test pieces cast in spiral molds from a wide range of carbon and chromium steels at 10, 30, and 50° C. above the liquidus demonstrate that the amount of superheat is the only dominant factor in determining such fluidities.

2. Late ore additions are not detrimental to surface condition of castings. (F. H. Allison, Jr., chief metallurgist, United Engineering & Foundry Co., Pittsburgh.) A late ore addition generally means that the heat has melted in at a lower state of oxidation. Such a heat may have a different slag condition and finish at higher phosphorus, sulphur, and silicon. But it will finish with a higher rate of carbon drop, and refine in shorter time. The combined effect of these factors should not be detrimental to the surface condition of steel castings.

3. Furnace practice may be identical for either ingots or castings. (R. W. Devine, plant superintendent, Erie Drop Forge Co., Erie, Pa.) The chemical specifications may differ (particularly in silicon), the method of deoxidation may be different, the pouring practice will certainly be different, but the melting, working, and shaping up may be the same.

4. Foaming acid openhearth ladle slags have no connection with the gas content of the metal. (T. J. Ondocsin, metallurgist, Mackintosh-

(Continued on p. 882)


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ACID MELTING

(Continued from p. 880)

Hemphill Co., Midland, Pa.) Foaming is held to be the result of inclusion in the slag of gaseous products of reactions which take place at the slag-metal interface. Foaminess is considered, then, as an attribute of the slag rather than of the metal, particularly of those chemical and physical properties which contribute to its viscosity.

5. Either a high rate of carbon drop or melting-in on a boil close to "go ahead" analysis produces the best physical properties. (G. S. Baldwin, chief metallurgist, Standard Steel Works Division, Baldwin Locomotive Works, Burnham, Pa.) These are the conditions for vigorous bath action. Note that in "melting-in close" the proposition states "on a boil". A fast carbon drop was defined as 0.60% per hr.; an average drop is 0.30% per hr. Good properties result from fast carbon drops, slowing up either naturally or with a block. For best quality, the heat should be out in 2½ hr., at the most, after melt-in. Poor properties result from slow working, whether caused by over pigging, melting too close and requiring repigging, high melt-in, or over-cautious working.

Foaming of Slag

Foaming of slag was discussed again in the session on metallurgy of the openhearth process, from the standpoint of the mechanism. The paper was written by B. M. Larsen, supervisor of process research metallurgy, U. S. Steel Corp. Research Laboratory, Kearny, N. J., to present "some speculative ideas with the hope of stimulating discussion and possibly some new ideas". Its purpose was accomplished. Disregarding the foaming which results from carbonaceous matter in the slag, the author considers reactions which may take place at the slag-metal interface, the gaseous products of which may not escape from the slag due to the lack of bubble size and momentum. Such foaming restricts the flow of heat to the bath and diffusion of oxygen to the deeper layers; this would prevent a good boil and, by concentrating oxygen at the interface, probably perpetuate the foaming condition. The consensus among the discussers attributes the cause to slag conditions, but there was no agreement as to the precise

(Continued on p. 884)

FOAMING OF SLAG

(Continued from p. 882)

factors involved — mentioned were slag temperature, composition, factors affecting viscosity, surface tension and effect of suspensoids (very controversial). Among the additions to slag, fine ore may cause foaming, exothermic additions and lime may stop it. The principal conclusion is that the subject is a timely one and needs investigation. As matters stand, the operator must meet the situation by doing something, and doing it quickly.

Deoxidation Practice

In the deoxidation of killed steel, the question of blocking the heat is still under discussion — whether and how much. It was mentioned by H. J. Forsyth, assistant director of steel conservation, Republic Steel Corp., Cleveland, that oxygen contents of baths containing more than one deoxidizing element are under investigation.

For open steel, controlled oxygen content is paramount; for rimming steel it must be sufficient to support a strong carbon-oxygen reaction, more for small ingots than for large ingots; for semi-killed, just under the amount needed for a strong reaction. Simon Feigenbaum, research engineer for Jones & Laughlin Steel Corp., Pittsburgh, pointed out that temperature control is essential to this, and is especially critical in capped steel. The present reporter would add close control of mold temperature for capped steel; it is reported to be impossible to control these ingots in hot molds. Among the advantages reported for capped steel are a good sound skin and less segregation, and a gain of 2% in yield over rimmed steel.

All-Basic Furnaces

Reports on the all-basic openhearths were presented — one at the Hamilton plant of Steel Co. of Canada, and one at South Works of Carnegie-Illinois. A. K. Moore, superintendent of openhearths, said that the Hamilton furnace is now operating with its sixth roof. In the first five campaigns, tonnages of 60,625 to 86,700 were produced, running 6.4 to 16.5% above the average tonnages with silica roofs. The cost-per-ton balance sheet looks like this: Increase in roof cost of 0.126 to 0.373, in fuel of 0.080 to 0.214; decrease in front and back-wall costs of 0 to 0.030, in fluxes of 0.006 to 0.009, in fixed costs of 0.165 to 0.264. This gives a net change ranging from a decrease of 0.005 per ton to an increase of 0.215 per ton, with increases showing in four of the five campaigns. Use of oxygen during the sixth campaign brings out the ability of the basic roof to withstand higher fuel rates. This is expected to increase the spread in tons per hour between the all-basic furnace and the basic lining with silica brick roof.

According to M. F. Yarotsky, superintendent of steel production, the South Works' furnace has operated since June 6, 1947, and produced over 1350 heats. It has operated under average shop conditions, except with a firing rate about 30% above shop average, and with oxygen and compressed air for flame enrichment. While it is still too early to draw conclusions, certain trends are indicated:

1. With the existing differential in cost, the quality of basic refractories and methods of construction

(Continued on p. 886)

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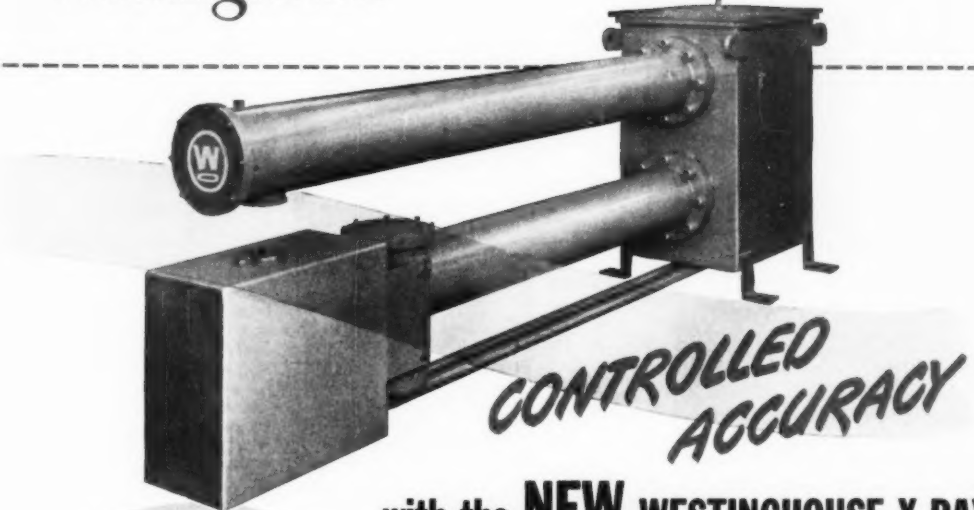

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X-RAY

BASIC FURNACES

(Continued from p. 884)

will have to improve to be competitive with silica brick.

2. The increase in production since conversion stands at 13% over shop average.

3. There is no significant variation in operating delay.

4. Fuel consumption is almost 7% higher than shop average, accounted for by increased firing rate and greater heat losses through the basic bricks.

5. There is no conclusive evidence of any metallurgical advantage.

6. Over-all economy is negative by approximately 2%.

It was proposed that this field of research could be "best served through systematic study of basic refractories".

Reports on basic ends by H. E. Warren, director of steel production of Homestead Works, Carnegie-Illinois, and by C. R. FonDersmith, superintendent of steel production of Armco Steel Corp., Middletown, Ohio, gave a detailed account of the original construction and subsequent repairs and replacement. It is concluded that this proposition has much merit from the standpoint of economy.

Notes on Refractories

Concerning hot metal mixer linings, sillimanite has shown improved life at some of the high-erosion spots, as reported by Addison Maupin, ceramic engineer of Republic Steel Corp., Cleveland. F. A. Colledge, masonry superintendent of Homestead Works, said that rammed linings have not been successful; they do not hold at the wash line. Some improvements can be made by perforating rammed linings, which allows moisture to escape and prevents separation of rammed layer from the foundation brickwork.

Roof life is dependent upon quality of silica brick, as determined by the effect upon refractoriness of alumina, titania, and the alkalis. Such details were recounted by H. M. Kraner, research engineer of Bethlehem. L. L. Wells, general supervisor of ceramic development for Carnegie-Illinois, discussed the effect of an alkali on the refractoriness of silica brick, saying that it is about 1.6 times that of an equal content of alumina.

(Continued on p. 888)

REFRACTORIES

(Continued from p. 886)

Analysis for Al_2O_3, as by spectrograph, is frequently sufficient to indicate the alkali present in particles of clay or mica, but where organic bonding agents are used, excess alkalis may be present.

Preparation of Blast Furnace Ore

Reports on the operation and effectiveness of blending of ores, especially for western blast furnaces, was a highlight of the Blast Furnace, Coke Oven and Raw Materials Conference. This development probably solves a problem which, not long ago, seemed a strong deterrent to the development of steel production in the West. The problem arises primarily from the low grade and nonuniformity of the local ores, but is greatly enhanced by the circumstance of a single haul from the mines to the furnaces, on a year-round basis. Contrast this with handling of lake ores, whose seasonal loading and stock-piling practices are well known.

Blending of these ores is accomplished by crushing, sizing, and bedding with a double-wing stacker coupled to a trailer tripper — equipment reminiscent of custom silver-lead smelters of the 1900 era. The ore is fed to the stacker on a belt and is thrown onto the beds while traversing at 60 to 110 ft. per min. In one installation, normally 960 layers are placed in a bed of 17,000 net tons of ore. While stacking two beds, two other beds are reclaimed for use by a machine which picks up a nearly vertical cut across all of these layers.

The effectiveness of this blending method is shown by comparative variations in analysis before and after, and by the spectacular improvements in furnace operation. In one installation variation in iron content between run-of-mine and reclaimed ore reduced from 46.2 to 63.9% to 51.5 to 55.4%; silica from 5.0 to 14.3% to 9.7 to 12.7%; alumina from 0.20 to 7.5% to 2.3 to 3.8%; lime from 1.0 to 3.8% to 1.7 to 3.1%; phosphorus from 0.067 to 0.130% to 0.088 to 0.110%; and sulphur from 0 to 0.04% to 0.004 to 0.008%. The daily average variation of silicon in the iron dropped from 0.57 to 0.25%. The total number of burden changes per month

(Continued on p. 889)

ORE PREPARATION

(Continued from p. 888)

dropped from 97 to 22. (Improvements effected by blending and sintering in the operation of the Fontana furnaces had already been reported by Mr. Saussaman at the 1948 conference.)

Operating data of large and small blast furnaces were compared by several speakers in a session on blast furnace operations. Large furnaces are affected more by changes in quality of raw materials than are the smaller ones, particularly with respect to weak coke which crushes more in the large furnaces. This will cause greater drops in wind rate and production, increase the chances of one-sided conditions or channeling, burn more copper in tuyeres and coolers, and necessitate greater care in guarding against tap hole troubles and sloppy tuyeres when taking off the wind.

Uniformity of product, as measured by the standard deviation in silicon content, is found to be better on small furnaces by one investigator, but better on large furnaces by three others. The coke rate on large furnaces is generally reported to be slightly lower. There is still a strong trend toward large furnaces; from 1935 to 1948 the number having hearth diameter 25 ft. and over increased from 2.3% of the total to 24.1%.

A study of the effect of coke stability on the operation of blast furnaces was reported by J. F. Peters, assistant superintendent of blast furnaces for Inland Steel Co., East Chicago. Stability is defined as the ability to withstand crushing, and is expressed as the percentage of a +2–3-inch sample which remains on a 1-in. screen after a standard tumbling test. This quality is found to correlate closely with the production of breeze, and both factors with variation in tonnage rates. When many fines are produced and coke stability is low, tonnage falls off, the wind may have to be cut to avoid high pressure and excessive hanging, and poor peripheral gas distribution and channeling become evident on the inwall temperatures.

On the subject of agglomerating of fine ores and flue dust, it was reported that good results are obtained in briquetting fine red hematites at Woodward, Ala., with portland cement as a binder. Two reports on nodulizing in cement

(Continued on p. 890)

ORE PREPARATION

(Continued from p. 889)

kilns show that good nodules can be produced by this method. Fine ore, or mixtures of ore and flue dust, are fluxed with limestone and fired at about 2400° F. Proportioning of the mixture is important. Large diameter kilns are best, to avoid trouble with built-up rings.

The sintering of iron concentrates at Ducktown and Copperhill, Tenn., was described. The raw material is produced by the flotation treatment of ores containing sulphides of iron, copper, and zinc. Typical concentrate analyses, on the dry basis, is 52.9% Fe, 43.0% S, and 0.9% SiO_2. It is roasted and sintered to 68.8% Fe, 0.05% S, and 1.2% SiO_2. The sulphur dioxide evolved is recovered for production of acid.

X-RAY MICROSCOPES

(Continued from p. 848)

it is unlikely that much greater magnification will be profitable with this method, because of the natural imperfection of the crystals that focus the rays.

None of these methods actually makes use of the potentially great resolving power of X-rays, as the graininess of the photographic emulsion is a limiting factor in the magnification that can be obtained in each method.

A new approach to the X-ray microscope is now being made, which avoids this limiting factor and may lead directly to a true X-ray microscope of superior resolving power.[4] It is a microscope in which the image is formed "with the aid of mirrors", as Paul Kirkpatrick, the inventor, points out in recent reports.

X-rays can be reflected from mirrors, provided the angle of incidence onto the mirror is within the small critical angle, which is in the neighborhood of 1°. Curved mirrors can, therefore, be used to focus the X-rays. A spherical mirror used with X-rays incident at a small angle does focus them, but astigmatism is bad. If the rays are reflected also from a second mirror, placed near the first with its face at right angles to the first, this successfully overcomes the astigmatism, but leaves spherical aberration in the

(Continued on p. 891)

X-RAY MICROSCOPES

(Continued from p. 890)

image. Kirkpatrick has reduced the aberration to a reasonable level by limiting the numerical aperture of the pair of mirrors to f 1000, which makes an undesirably slow "lens" system, and destroys much of the gain in resolving power that X-rays should contribute.

Spherical aberration can be avoided better by avoiding spheres and going to a pair of ellipsoidal mirrors (the contour of which can be provided by the controlled deposition of metal vapor). The principle works, but the useful magnifications that can be reached have not yet been determined; they should lie in the range between the ultraviolet microscope and the electron microscope, and theory puts the limit of resolution at 70 angstrom units. This limit is independent of wave length, because the gain in resolving power with decrease in wave length is nullified by a decrease in aperture caused by the inevitable decrease in critical angle.

One would expect this X-ray microscope, when perfected, to be useful in connection with either the microradiography, the X-ray reflection micrography, or the microanalyzer mentioned earlier, and to do at higher magnifications what these techniques are now capable of doing at low magnifications. It appears likely that considerable time will elapse before a state of perfection is reached, for the present models represent several years' research and permit only moderate magnifications; a picture has been reproduced that showed good resolution at 30 × magnification. One of the difficult problems in further development is the high degree of perfection required in the mirror surfaces.

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(Continued on p. 892)

X-RAY MICROSCOPES

(Continued from p. 891)
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4. Paul Kirkpatrick, *Scientific American*, March 1949, p. 44-47, and papers presented before the American Physical Society; Paul Kirkpatrick and A. V. Baez, *Journal of the Optical Society of America*, Vol. 38, 1948, p. 766-774.

NEW ULTRAVIOLET MICROSCOPE*

THIS PAPER reveals a new instrument for scientific research that has been developed in the research laboratory of the Polaroid Corp., with the support of the Office of Naval Research.

In its present form, the new microscope has more immediate applicability to biological problems than to the physical sciences, but there is every reason to expect that it may be of equal importance in the study of metallic surfaces.

Two objectives, one of a reflecting type and one of a combined reflecting-refracting type, having numerical apertures of 0.4 and 0.72 respectively, have been designed and constructed. These lenses fit into a standard microscope stand. They may be used as condensers as well as objectives. An achromatic quartz-fluorite ultraviolet condenser has also been provided, and lenses of higher numerical aperture are now being developed.

Instead of being like previous ultraviolet instruments, suitable only for use with a single wave length (monochromatic), the new microscope is both achromatic and apochromatic from 220 to 800 $m\mu$. This has led to a new conception of the method of using an ultraviolet microscope. Three different ultraviolet wave lengths from a superhigh-pressure mercury arc are selected successively by means of a Wadsworth-type grating mono-

(Continued on p. 894)

*Abstracted from "A Color-Translating Ultraviolet Microscope", by E. H. Land, E. R. Blout, D. S. Grey, M. S. Flower, H. Husek, R. C. Jones, C. H. Matz and D. P. Merrill, *Science*, April 15, 1949, p. 371-374.

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(Continued from p. 892)

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METAL PROGRESS

Volume 55; January 1949 to June 1949

Ernest E. Thum
Editor

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William H. Eisenman
Business Manager

Table of Contents for Vol. 55

(a) Abstract; *(b)* Biography; *(c)* Correspondence; *(cp)* Critical Points; *(d)* Data Sheet.

List of Authors

(a) Abstract; **(b)** Biography; **(c)** Correspondence; **(cp)** Critical Points; **(d)** Data Sheet.

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